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Faint Standards for *ZYJHK* from the UKIDSS and VISTA Surveys

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ABSTRACT
The currently defined "UKIRT Faint Standards" have *JHK* magnitudes between 10 and 15, with $K_{\rm median}$ = 11.2. These stars will be too bright for the next generation of large telescopes. We have used multi-epoch observations taken as part of the UKIRT Infrared Deep Sky Survey (UKIDSS) and the Visible and Infrared Survey Telescope for Astronomy (VISTA) surveys to identify non-variable stars with *JHK* magnitudes in the range 16 – 19. The stars were selected from the UKIDSS Deep Extragalactic Survey (DXS) and Ultra Deep Survey (UDS), the WFCAM calibration data (WFCAM-CAL08B), the VISTA Deep Extragalactic Observations (VIDEO) and UltraVISTA. Sources selected from the near-infrared databases were paired with the Pan-STARRS Data Release 2 of optical to near-infrared photometry and the Gaia astrometric Data Release 2. Colour indices and other measurements were used to exclude sources that did not appear to be simple single stars. From an initial selection of 169 sources, we present a final sample of 81 standard stars with *ZYJHK* magnitudes, or a subset, each with 20 to 600 observations in each filter. The new standards have $Ks_{\rm median}$ = 17.5. The relative photometric uncertainty for the sample is < 0.006 mag and the absolute uncertainty is estimated to be $\lesssim$ 0.02 mag. The sources are distributed equatorially and are accessible from both hemispheres.

Key words: standards – methods observational – techniques photometric

1 INTRODUCTION

Optical and infrared sky surveys have produced data with excellent astrometric and photometric precision. In 2019, we are benefiting from data releases by ground- and space-based surveys that were many years in the planning.

The Gaia mission (Gaia Collaboration et al. 2016) issued Data Release 2 on 2018 April 25. This release contains astrometric results for about 1.7 billion stars brighter than optical magnitude 21; parallaxes and proper motions are given for about 1.3 billion of these (Gaia Collaboration et al. 2018). The Sloan Digital Sky Survey (SDSS, York et al. 2000) and the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS, Chambers et al. 2016) have imaged large areas of the Northern sky in blue/green to far-red/near-infrared filters. Tonry et al. (2012) give transformations between the SDSS and Pan-STARRS photometric systems. After transformation, the rms difference between the SDSS and Pan-STARRS *griz* photometry is 8 mmag, following a recalibration of the SDSS photometry with new flat fields and zero points derived from Pan-STARRS (Finkbeiner et al. 2016). This is consistent with Padmanabhan et al. (2008) who report a relative calibration accuracy of 0.7 – 1.3% for each filter in the SDSS.

Several near-infrared surveys of the sky have been undertaken in the last two decades. The 2-micron All Sky Survey (2MASS, Skrutskie et al. 2006) was executed between 1997 and 2001, with 1.3 m telescopes in both hemispheres providing complete sky coverage. The UKIRT Infrared Deep Sky Survey (UKIDSS, Lawrence et al. 2007) consisted of several Northern-hemisphere sub-surveys using the WFCAM camera and *ZYJHK* filters, and was executed between 2007 and 2011 on the 3.8 m UKIRT on Mauna Kea. Following UKIDSS, in 2012, the UKIRT Hemisphere Survey (UHS, Dye et al. 2018) began, and aims to provide continuous coverage in the *J* and *K* bands over the Declination range of zero to +60 degrees. A collaboration between the University of Hawaii and the United States Naval Observatory is continuing the UKIRT survey and adding the *H* band (Hodapp et al. 2018). In the Southern hemisphere, the 4.1 m Visible and Infrared Survey Telescope for Astronomy (VISTA Sutherland et al. 2015) started surveying the sky

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in 2009; the first surveys are complete or nearing completion as of 2019[1]; VISTA is producing several sub-surveys using the *ZYJHKs* filters, or a subset. González-Fernández et al. (2018) compare the VISTA and UKIDSS photometric systems using equatorial stars observed with both cameras. The differences are small, and after transformation the rms difference between the measurement sets is 1 – 3 mmag at *JHK*.

The near-infrared surveys cover the entire sky and provide 1 – 10 sources per square arcminute on average. Such stars could be used to calibrate science data to ~10% (González-Fernández et al. 2018; Hodgkin et al. 2009). Photometric standard stars are needed to calibrate data more accurately. In the near-infrared these have frequently been provided by UKIRT measurements published by Hawarden et al. (2001) and Leggett et al. (2006). The UKIRT Faint Standards (FS) cover a range in Declination of −25 to +55 degrees. They have *JHK* Vega magnitudes of 10 – 15 with $K_{\rm median} = 11.2$ and $\sigma_{\rm median} = 0.01$. The UKIRT FS require integration times of 1 – 10 seconds when observed on 8 m telescopes such as at the Gemini Observatory. On future telescopes with diameters three or more times larger, the integration times will be < 1 s; such short integrations are not only inefficient, they may give rise to calibration problems such as poor linearity corrections (e.g. Leggett et al. 2006).

In this paper we identify stars in the UKIDSS and VISTA surveys that are fainter than the UKIRT FS by a factor of ~100. We select sources that have a large number of repeat measurements which show them to be non-variable, and which have high precision photometric measurements. We pair the list of candidates with the Pan-STARRS and Gaia databases and use the optical and near-infrared colours to refine the sample and produce a set of well-measured and well-behaved single stars.

2 THE SURVEYS

The Northern hemisphere UKIDSS (with the WFCAM camera) and the Southern hemisphere VISTA use similar-size telescopes, and similar filters defined according to the Mauna Kea Observatories filter specifications (Tokunaga et al. 2002). Survey data generated by both telescopes are initially processed by the Cambridge Astronomy Survey Unit (CASU) and then transferred to the Wide-Field Astronomy Unit (WFAU) in Edinburgh for further processing and archiving (Cross et al. 2012; Hambly et al. 2008). Table 1 gives a summary of the properties of the surveys used in this work.

Each of the surveys has a source table (e.g. `dxsSource`) which contains band-merged detections from deep images. In addition, for the surveys used here, there is a variability table (e.g. `dxsVariability`) which contains the light-curve statistics for each primary source that is detected in at least one epoch. Details of the multi-epoch table structure and processing can be found in Cross et al. (2009). The number of good observations for each filter and each source is given as `nGoodObs` in the variability table; these are measurements which are not flagged as blended, saturated, etc. using the post-processing error bit flag (`ppErrBits`), i.e. a good observation has `ppErrBits=0`[2]. The source and variability tables share the same primary key **sourceID**.

Our goal is to identify stars that are not variable, that have well-measured *JHK* magnitudes, and are fainter than $K = 16$. Therefore we only used surveys with variability tables for all of the J, H, and K filters. This means we include the UKIDSS Deep Extragalactic Survey (DXS), Ultra Deep Survey (UDS) and WFCAMCAL calibration data, but do not include the UKIDSS Galactic Clusters, Galactic Plane or Large Area Surveys (GCS, GPS, LAS). Similarly we use the VISTA Deep Extragalactic Observations Survey (VIDEO) and UltraVISTA surveys, but do not include the VISTA Kilo-Degree Infrared Galaxy, Magellanic Clouds, Variables in the Via Lactea, or Hemisphere Surveys (VIKING, VMC, VVV, VHS). The DXS, UDS, WFCAMCAL and VIDEO surveys are complete. The UltraVISTA survey is being continued[3] with a final data release planned for 2021[4].

The variability flag for each source (`variableClass`) is determined from repeat measurements and is stored in the variability table (Cross et al. 2009). The value is determined by the significance of the weighted average of the intrinsic noise over the expected noise, as given by a noise model for each pointing and each band. The weighting of the intrinsic noise is based on the number of good observations: $w_f = \frac{N_{obs,f} - N_{min}}{N_{obs,max} - N_{min}}$, where $N_{min} = 5$ is the minimum number of observations necessary to measure variability, $N_{obs,f}$ is the number of good observations in that

Table 1. Overview of the Sky Survey Data

Survey Name	Area deg^2	Filters	Vega mag 5σ Limits	Ref.
UKIDSS Deep Extragalactic Survey (DXS)	35.0	*JHK*	21 – 22	1
UKIDSS Ultra Deep Survey (UDS)[a]	0.8	*JHK*	23 – 25	1
VISTA Deep Extragalactic Observations (VIDEO)	12.0	*ZYJHKs*	24 – 25	2
VISTA UltraVISTA[b]	1.5	*YJHKs*	22 – 24	3
WFCAM Calibration WFCAMCAL08	10.4	*ZYJHK*	18 – 19	4

References: (1) Lawrence et al. (2007), (2) Jarvis et al. (2013), (3) McCracken et al. (2012), (4) Ferreira Lopes et al. (2015).

[a] For the UDS, the source table aperture magnitudes are not aperture corrected and the variability table mean magnitudes are. For a sample of 30 objects, we find an average offset in photometry of 0.190 ± 0.005, 0.202 ± 0.006, and 0.179 ± 0.006, at J, H and K respectively, such that the mean magnitudes are brighter.

[b] For UltraVISTA there are differences in the aperture corrections and zeropoints used for the source table aperture magnitudes and the variability table mean magnitudes. For a sample of 19 objects we find `meanMag − aperMag3` = 0.020±0.005, 0.052±0.006, −0.025±0.010, and −0.004±0.012 at Y, J, H and Ks respectively.

[1] https://www.eso.org/sci/observing/PublicSurveys/sciencePublicSurveys.html

[2] http://wsa.roe.ac.uk/ppErrBits.html

[3] https://www.eso.org/sci/observing/PublicSurveys/sciencePublicSurveys.html#vistacycle2

[4] https://www.eso.org/sci/observing/PublicSurveys/docs/UltraVISTA2_SMP_03022017.pdf

band, and $N_{obs,max}$ is the maximum number of good observations for the star in any band. The default classification is non-variable (`variableClass` = 0), and if a star has fewer than 5 good observations in all bands it will be classified as non-variable; none of the objects selected here fall into this category. If a star has fewer than 5 observations in all bands but one, that band will determine the classification. If there are hundreds of observations in one band and tens in the others, the band with hundreds will have a strong weighting compared to the others. The star is classified as variable (`variableClass` = 1) if the ratio of the weighted intrinsic noise to the expected noise is > 3.

We adopt the mean photometric magnitudes and uncertainties given in the variability tables as the reference calibration data in this work, and not the source table aperture magnitudes, for the following reasons. In some cases, the source tables do not go as deep as the stacked variability images; this is the case for the WFCAMCAL08 database where it was important to avoid source blending for calibration purposes. For the Ultra Deep Survey the source table photometry `AperMag` is not aperture-corrected, while the variability photometry `MeanMag` is (Table 1, Section 3). For the most recently processed survey, UltraVISTA, there are small differences between the variability and source table photometry due to different aperture corrections and Vega-to-AB zeropoint corrections (Table 1, Section 3). These issues will be corrected in a forthcoming UltraVISTA release. The variability photometry is processed in the same way for all the surveys used here, and so provides a self-consistent sample.

3 THE SQL SELECTIONS

We used the WFCAM Science Archive[5] and the VISTA Science Archive[6] to query the DXS, UDS, UltraVISTA, VIDEO and WFCAMCAL databases. The most recent data releases available at the time of writing were used: Data Release 11 of the DXS and UDS was used, Data Release 4 for UltraVISTA, Data Release 5 for VIDEO, and WFCAMCAL08B. For all surveys we selected for the photometric source to be the same as the source in the variability catalogue and for non-variable sources, for example `SELECT FROM dxsSource AS s, dxsVariability AS v WHERE s.sourceID=v.sourceID AND v.variableClass=0`.

We selected for point sources using the surveys' morphological classifications. For the shallower surveys – DXS and WFCAMCAL – the classification scheme uses a statistic which describes how point-like each object is with respect to an empirically derived, idealized radial profile representing the point source function (PSF) for the frame (Irwin et al. 2004; Hambly et al. 2008). The deeper surveys – UDS, UltraVISTA and VIDEO – use the TERAPIX SWARP image resampling tool (Bertin et al. 2002) and the CLASS_STAR statistic[7] generated by the SEXTRACTOR software (Bertin & Arnouts 1996), together with magnitude cuts in each band (Liske et al. 2003; Warren et al. 2007). We found that we could select a good-sized sample of objects (more than ten) from each of the DXS, UDS, and WFCAMCAL surveys by selecting for stars only, using `s.mergedClass=-1`. For VIDEO we relaxed the selection to stars and probable stars, with `s.mergedClass in (-1, -2)`, in order to get a useful sample. For UltraVISTA we found that the mergedClass statistic in the source table classifies all sources with multi-filter photometry as galaxies. A visual inspection of the sources in the stacked images showed that the PSFs in the Y and J images are extended. We expect that future releases of the ongoing UltraVISTA survey will include improved morphological classifications. For this work, for UltraVISTA, we selected for possible stars by using the class statistic determined from the H and K images, `s.hclassStat>0.7 AND s.ksclassStat>0.7`, and we use additional profile and colour selections to separate galaxies from stars (Section 6).

We selected for precise photometry by restricting the uncertainty in the mean magnitude to $\leq$ 0.006 mag. The photometric uncertainties are given in the variability catalogue by the rms value of the multiple measurements (`MagRms`) and the median absolute deviation of the magnitude (`MagMAD`): we selected for sources where these values scaled as expected with `nGoodObs`, for example `(v.jMagMAD/SQRT(v.jnGoodObs - 1))<=0.004 AND (v.jMagRms/SQRT(v.jnGoodObs - 1))<=0.006`.

For the DXS, VIDEO and WFCAMCAL surveys we selected for consistency between the source and variability table magnitudes by limiting the difference to 2.5 σ where σ is determined from the variability rms and the source aperture magnitude error, for example, `(s.jAperMag3 - v.jMeanMag) < 2.5 * (SQRT( s.jAperMag3err * s.jAperMag3err + (v.jMagRms/SQRT(v.jnGoodObs - 1)) * (v.jMagRms/SQRT(v.jnGoodObs - 1))))`. For the UDS and UltraVISTA surveys, where there are systematic differences between the source and variability table magnitudes (Section 2 and Table 1), we selected for objects with a small range around the average offset; for example for the UDS we used `(s.jAperMag3 - v.jMeanMag < 0.20) AND (s.jAperMag3 - v.jMeanMag > 0.18)`, and for UltraVISTA we used `((s.jAperMag3 - v.jMeanMag) <= -0.04) AND ((s.jAperMag3 - v.jMeanMag) >= -0.08)`.

A limit on target declination was also implemented. In Sections 6 and 7 we use Pan-STARRS optical data, together with the near-infrared data, to further refine the star/galaxy separation and to remove sources which may be multiple, as evidenced by unusual colours. For this reason we restricted our searches to declination $> -30°$.

The constraints on brightness and number of observations in each filter varied with each survey. Sources with $K > 16$ or $K > 16.5$ were selected from the DXS, UltraVISTA and WFCAMCAL, while sources with $K > 17.5$ were selected from the deeper UDS and VIDEO surveys (Table 1). For the data to be of calibration quality, we adopt a minimum number of measurements of 20 for each object in each filter. Less than twenty H-band observations were obtained for some objects in the DXS, and for that survey we restricted the search to a minimum of 20 observations in J and K and 5 in H, in order to use the colour information. The minimum number of observations for the other surveys ranged from 20 to 100 for each filter. While the JHK filters

[5] http://wsa.roe.ac.uk
[6] http://surveys.roe.ac.uk/vsa
[7] https://sextractor.readthedocs.io/en/latest/ClassStar.html

are our priority in this work, we also record the Z and Y magnitudes where available.

The SQL queries used for each survey in their complete form are given in the Appendix. The searches produced 169 sources: 34 from the DXS, 51 from the UDS, 25 from UltraVISTA, 47 from the VIDEO survey, and 12 from WFCAM-CAL.

4 THE WFCAM-UKIDSS AND VISTA PHOTOMETRIC SYSTEMS

Both WFCAM and VISTA use filters specified by the Mauna Kea Observatories system (Tokunaga et al. 2002). There are small differences in the filters as delivered, and differences in the site and telescope optics, which lead to small differences between the native UKIDSS and VISTA photometric systems. González-Fernández et al. (2018) use a large sample of reddening-free stars with photometric errors < 0.1 mag, observed with both cameras, to derive the following color transformations between VISTA and WFCAM:

$$Z_V - Z_W = -(0.037 \pm 0.008) \times (J-K)_W + (0.040 \pm 0.005)$$

$$Y_V - Y_W = -(0.010 \pm 0.003) \times (J-K)_W - (0.048 \pm 0.002)$$

$$J_V - J_W = -(0.028 \pm 0.002) \times (J-K)_W - (0.004 \pm 0.001)$$

$$H_V - H_W = -(0.037 \pm 0.001) \times (J-K)_W + (0.025 \pm 0.001)$$

$$Ks_V - K_W = (0.017 \pm 0.003) \times (J-K)_W - (0.022 \pm 0.002)$$

VISTA survey observations are continuing, and the photometry presented here can be enhanced by future UltraVISTA data releases, hence we convert the UKIDSS photometry to the VISTA system and use that as our reference system in this work.

The UKIDSS UDS field (Data Release 11) and the VISTA VIDEO XMM-Newton field (Data Release 5) overlap by 0.1 deg in Right Ascension and 0.9 deg in Declination. A search for non-variable point sources in the common region with `AperMag3err` ≤ 0.006 produced a sample of 43 stars with H and K magnitudes between 13 and 16 (no J measurements were available). Allowing for small color transformations (see above), we find a mean difference between the UDS and VIDEO survey magnitudes of 0.010 mag at H and K. These results suggest that the color-transformed standard star photometry presented in this paper is robust at the 1% level.

5 MATCHING TO PAN-STARRS AND GAIA

The coordinates of the sources produced by our SQL searches of the WFCAM and VISTA science archives, described above, were matched to Data Release 2 of the Pan-STARRS data archive[8] and Data Release 2 of the Gaia data archive[9], which were the most recent releases at the time of writing. The Pan-STARRS *grizy* magnitudes ranged from 18 to 23.

For about one-third of the sample, one or two of the Pan-STARRS filters have an aperture and PSF magnitude that differ by more than 2.5σ. About 60% of these we identify as possible galaxies below. The majority of the remainder have PSF and aperture magnitude differences that are not large in absolute terms, and it is possible that the uncertainties are slightly underestimated in this Pan-STARRS release.

Sources with Pan-STARRS AB magnitudes $r \lesssim 21$ and $i \lesssim 20.5$ were detected by Gaia, consistent with the $G < 21$ limit of Gaia Data Release 2 (Gaia Collaboration et al. 2018). Of those, about 85% have proper motion measurements (all $\lesssim$ 30 mas yr^{-1}). About one-third of the sources with proper motion measurements have a trigonometric parallax measurement that is positive and has an uncertainty smaller than the parallax measurement. Fifteen of the 169 objects found in our searches have a Gaia parallax measurement that is significant. The next release of Gaia data, expected in the third quarter of 2020, will include additional and improved astrometry[10].

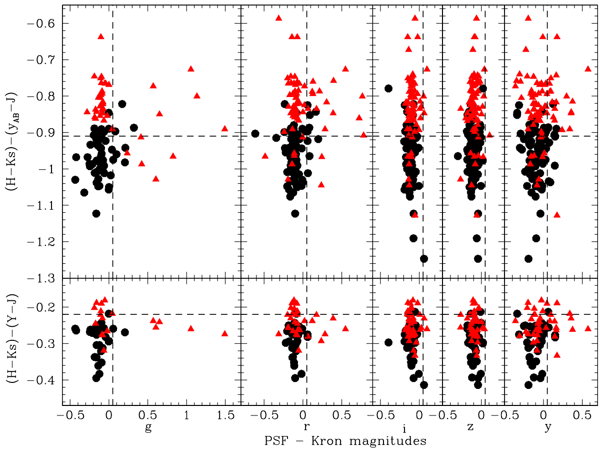

Figure 1. Red triangles are identified as possible galaxies either by the PSF − Kron magnitude or the colour index. The limits on these values are indicated by the dashed lines, see Section 6.

6 STAR/GALAXY SEPARATION

Our goal here is to provide as clean a sample as possible of truly point source calibrators, so that, even if imaged at very high resolution, the aperture corresponding to the photometry is unambiguous. We therefore further prune the sample by excluding possible galaxies.

Davies et al. (2018) determined that stars and galaxies can be separated in VISTA data by using a near-infrared colour index. Davies et al. (2018) select for galaxies by applying the colour cut $(H - Ks) - (Y - J) > -0.26$, and verified the selection by visual inspection of objects brighter than $Y = 21.2$. Not all of our sample has a Y-band measurement and we determined the $(H - Ks) - (y_{AB} - J)$ color, replacing the VISTA Y_{Vega} with the Pan-STARRS y_{AB} magni-

[8] https//catalogs.mast.stsci.edu/
[9] https//gea.esac.esa.int/archive/
[10] https://www.cosmos.esa.int/web/gaia/release

tude. Calibrating that index against the VISTA index, we adopt as a stellar indicator $(H-Ks)-(Y-J) < -0.22$ or $(H-Ks)-(y_{AB}-J) < -0.91$.

We also explored the use of the Pan-STARRS PSF and Kron magnitudes, searching for the brighter Kron magnitudes that would be expected if the source was extended (e.g. Chambers et al. 2016, their Figure 19). Chambers et al. (2016) find that stars can be selected by PSF − Kron < 0.05 magnitude, for magnitudes as faint as ~ 21.

Figure 1 combines these two indicators, plotting $(H-Ks)-(Y-J)$ and $(H-Ks)-(y_{AB}-J)$ against PSF − Kron magnitudes for each of the Pan-STARRS filters. The star/galaxy cuts are shown in the Figure; we excluded as possible galaxies sources which are either too red in one or both of the color indices, or too bright in any of the PSF − Kron colours. The sources that remain are shown in black in Figure 1, and lie to the lower left, or have error bars that would place them in the lower left, of each panel (error bars are omitted from the Figure for clarity). These cuts identified 77 of the 169 sources as possible galaxies, and we omit them from the standard star sample. The Appendix Table B1 lists the possible galaxies together with Pan-STARRS and VISTA-system photometry, and Gaia data where available.

7 EXCLUSION OF MULTIPLE SYSTEMS AND OTHER CONTAMINANTS

We further refine the likely-star sample of 92 objects by excluding sources with atypical colours. These may be multiple systems, or the colours may be compromised in some way. To produce a conservative sample, we reject outliers from colour sequences prescribed by the majority of the sample. Figure 2 shows bluer colors — $g_{AB}-r_{AB}$, $r_{AB}-i_{AB}$, $i_{AB}-z_{AB}$ — and Figure 3 redder colours — $z_{AB}-y_{AB}$, $y_{AB}-J_{Vega}$, $J_{Vega}-H_{Vega}$. We identify 7 sources as outliers; these are shown as open circles in Figures 2 and 3 and listed in Appendix Table C1.

Figures 2 and 3 include color sequences produced by stellar model atmospheres. We used the BT-SETTL models (Allard et al. 2012; Baraffe et al. 2015) and the PARSEC models (Bressan et al. 2012; Girardi et al. 2000), for a range of metallicity as described in the Figure caption. For both model sets the $g-r$ colour deviates significantly from observation for M-type stars; this may be due to some issue common to the model atmospheres or it may be due to errors in the g bandpass adopted by both modelling groups, which could introduce a colour term. The colors and absolute magnitudes (where available), combined with the models, imply that the sample consists of dwarf stars with masses between 0.1 and 1.0 $M_{\odot}$.

Lastly, for the DXS, VIDEO and WFCAMCAL surveys, where there is no offset between the source table aperture magnitudes and the variability table mean magnitudes (Sections 2, 3), we excluded sources where these values deviated significantly. The earlier selections excluded discrepant sources based on the variability rms, now we exclude sources based on the variability MAD values. We excluded sources where the aperture and mean magnitudes differed by > 0.03 mag *and* the difference was significant by $> 2.5\,\sigma$. Four additional objects were rejected by this criterion and

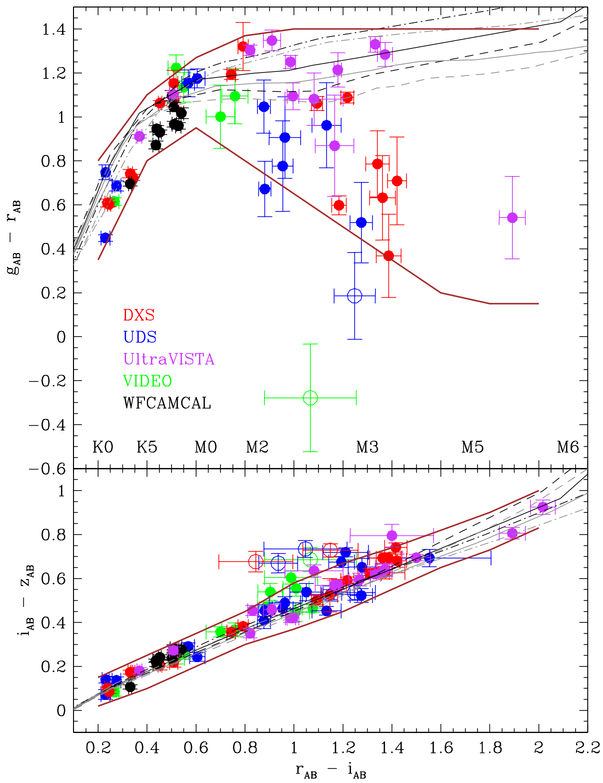

Figure 2. Colours of the likely stellar sources. No reddening correction has been applied. Open circles are objects with one or more colours that deviate from the loci identified by the sample. The thinner lines are model isochrones from the BT-SETTL set (black, Allard et al. (2012); Baraffe et al. (2015)) and the PARSEC set (grey, Bressan et al. (2012); Girardi et al. (2000)). For these sequences, age in Gyr and [m/H] are: 5, 0.0 (solid line); 1.0, +0.3 (dashed line); 10, −0.5 (dash-dot line). The thick brown lines indicate the regions adopted here as defining normal star colours. Two sources are excluded in the top panel, being either too blue in $g_{AB}-r_{AB}$ or in $r_{AB}-i_{AB}$. One of these is also an outlier in the lower panel, along with four other sources that appear too blue in $r_{AB}-i_{AB}$ or too red in $i_{AB}-z_{AB}$. Spectral types along the x axis are from the relationship between $r_{AB}-i_{AB}$ and type given by Covey et al. (2007).

these are listed in Appendix Table C2. All of these rejected sources are at the faint end of the associated survey.

After exclusion of these 11 objects, the final sample consists of 81 stars ranging in spectral type from K2 to M6.

8 FINAL SAMPLE

Table 2 compiles the Pan-STARRS, UKIDSS/VISTA and Gaia data for the final sample of 81 stars. Spectral types are also given; these are estimated from the $r_{AB}-i_{AB}$ color (Covey et al. 2007) where available. Where this color was not available the type was estimated by interpolating the $i_{AB}-z_{AB}$ or $y_{AB}-J_{Vega}$ colors, using stars with all three colors to define the relationships.

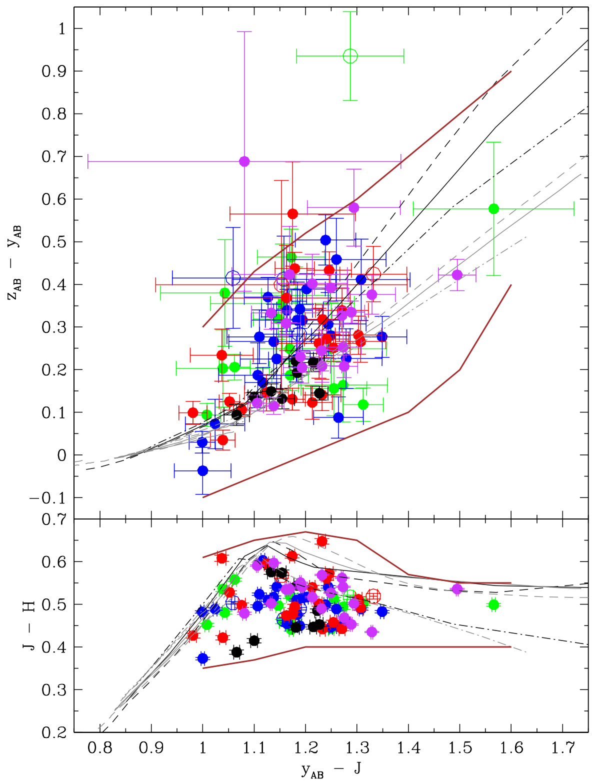

Figure 3. Colours of the likely stellar sources with symbols and lines as in Figure 2. No reddening correction has been applied. In addition to the 6 outliers identified in Figure 2, one additional outlier is identified in the upper panel, as too red in $z_{AB} - y_{AB}$ or too blue in $y_{AB} - J$.

Table 2. Data for Final Sample

IR Survey Name	RA° Decl.°	Spectral Type	Gaia RA° ± mas	Gaia Decl.° ± mas	Parallax ± mas	μ RA ± mas yr^{-1}	μ Decl. ± mas yr^{-1}	G	Pan-STARRS meanPSF AB mags *g* ±	*r* ±	*i* ±	*z* ±	*y* ±	VISTA Vega mags *Z* ±	*Y* ±	*J* ±	*H* ±	*Ks* ±
UDS	34.0342392	M3.5								21.7683	20.5566	19.8377	19.5578			18.3094	17.8626	17.5573
	-5.1728814									0.0918	0.0133	0.0158	0.0340			0.0020	0.0018	0.0032
UDS	34.0585392	M3								21.6694	20.5205	19.9937	19.6780			18.4943	18.0184	17.7527
	-5.3530358									0.1112	0.0192	0.0112	0.0886			0.0020	0.0020	0.0032
UDS	34.0906904	M2.5	34.090724762816	-5.187250050454				20.8948	22.0173	21.1110	20.1476	19.6591	19.5706			18.3070	17.8586	17.5862
	-5.1871909		1.72235	2.62332					0.1755	0.0610	0.0198	0.0199	0.0440			0.0020	0.0020	0.0031
UDS	34.1166206	M0	34.116703956194	-5.433148535694		31.4547	-14.0542	20.5484	21.6757	20.5011	19.8962	19.6520	19.4654			18.3581	17.8624	17.6619
	-5.4330768		1.13832	1.14117		1.9471	1.7836		0.0312	0.0299	0.0088	0.0175	0.0736			0.0020	0.0018	0.0032
UDS	34.1459342	M3								21.9087	20.6313	19.9788	19.5901			18.3878	17.8711	17.5971
	-5.4192513									0.0484	0.0303	0.0248	0.0264			0.0021	0.0018	0.0033
UDS	34.1559576	M3							22.4436	21.4817	20.3488	19.8964	19.6713			18.4886	17.9790	17.7385
	-5.1864870								0.1855	0.0578	0.0138	0.0136	0.0520			0.0021	0.0020	0.0033
UDS	34.1991747	M2	34.199178767942	-4.947697715516				20.8574	22.0767	21.0300	20.1533	19.7429	19.4767			18.3392	17.8223	17.5819
	-4.9476391		2.11700	2.55827					0.1193	0.0229	0.0130	0.0348	0.0801			0.0021	0.0019	0.0033
UDS	34.2232606	M2.5							22.0736	21.2984	20.3444	19.8807	19.6561			18.5122	17.9708	17.7333
	-4.7491396								0.2023	0.0397	0.0146	0.0271	0.0661			0.0022	0.0021	0.0034
UDS	34.2308454	M3								21.7580	20.5639	19.8892	19.5468			18.3580	17.9076	17.6218
	-5.3911233									0.0466	0.0234	0.0114	0.0442			0.0021	0.0020	0.0032
UDS	34.3103343	M4.5									20.9380	20.1853	19.9076			18.5593	18.0758	17.7539
	-5.4172864										0.0301	0.0446	0.0168			0.0022	0.0018	0.0034
UDS	34.3240632	M5									20.9455	20.1946	19.7373			18.4768	17.9876	17.6696
	-5.4334966										0.0271	0.0264	0.0933			0.0023	0.0020	0.0034
UDS	34.3475622	M3							22.1287	21.6100	20.3351	19.8115	19.5857			18.3072	17.8462	17.5767
	-5.4844981								0.1780	0.0413	0.0208	0.0229	0.0656			0.0020	0.0018	0.0032
UDS	34.3750969	M4								22.2721	20.7193	20.0259	19.7191			18.4748	17.9338	17.6445
	-5.4848715									0.2496	0.0288	0.0261	0.0687			0.0022	0.0019	0.0034
UDS	34.4389254	M3								21.5469	20.3938	19.8619	19.4921			18.3653	17.8549	17.6085
	-5.4868910									0.0350	0.0244	0.0254	0.0394			0.0021	0.0020	0.0033
UDS	34.5319836	M2							21.7700	21.0978	20.2171	19.7631	19.4859			18.3762	17.8516	17.6315
	-5.1015107								0.1245	0.0211	0.0142	0.0218	0.0591			0.0020	0.0018	0.0033
UDS	34.6700469	M5.5									20.8852	20.0903	19.5863			18.3469	17.8485	17.5109
	-5.0787756										0.0378	0.0342	0.0477			0.0024	0.0020	0.0036
UDS	34.6776197	M2.5								21.5419	20.4913	19.9533	19.6368			18.4426	17.9281	17.6586
	-4.9671258									0.0643	0.0223	0.0325	0.0645			0.0022	0.0019	0.0035
UDS	34.7079081	K3	34.707936489500	-4.903956579988		6.0938	-0.6828	19.8705	20.3459	19.6602	19.3849	19.2484	19.1746			18.1506	17.6618	17.5555
	-4.9039390		1.49577	1.02274		2.2974	1.7844		0.0188	0.0144	0.0105	0.0102	0.0573			0.0017	0.0017	0.0029
UDS	34.7425103	K2	34.742551524244	-5.478149266917		-1.6880	-2.0504	19.7838	20.4217	19.6735	19.4427	19.3034	19.2729			18.2738	17.7916	17.6957
	-5.4781043		0.84654	0.62984		1.3900	1.0100		0.0316	0.0109	0.0086	0.0109	0.0226			0.0019	0.0018	0.0029
UDS	34.7745424	M5									20.9764	20.1684	19.7567			18.4493	17.9604	17.6400
	-4.8889668										0.0321	0.0280	0.0913			0.0022	0.0020	0.0034
UDS	34.8172698	M4									20.8266	20.1456	19.8074			18.6426	18.1886	17.9029
	-4.7942724										0.0220	0.0338	0.0365			0.0022	0.0019	0.0033
UDS	34.8182276	K7	34.818219802904	-5.106312522351				20.6559	21.8021	20.6494	20.0812	19.7897	19.6196			18.5033	17.9004	17.7308
	-5.1062739		1.77157	1.21047					0.0558	0.0243	0.0099	0.0119	0.0328			0.0021	0.0019	0.0034
UDS	34.8710949	K2	34.871103834372	-5.115517311973		6.0251	-7.9278	19.6855	20.0623	19.6130	19.3828	19.3110	19.3479			18.3481	17.9747	17.8797
	-5.1154861		0.67365	0.56550		0.9709	0.8974		0.0075	0.0131	0.0133	0.0175	0.0523			0.0016	0.0019	0.0029
VIDEO	35.0542019	M0							21.9615	20.9614	20.2612	19.9043	19.7169		19.0018	18.5465	18.0267	17.8310
	-4.4813805								0.1321	0.0562	0.0170	0.0159	0.0324		0.0021	0.0028	0.0047	0.0043
VIDEO	35.1152774	M4.5									20.8536	20.1628	19.6987		19.0704	18.5271	18.0857	17.8255
	-4.9003215										0.0245	0.0260	0.0604		0.0020	0.0021	0.0032	0.0049
VIDEO	35.3795003	M2.5								21.5975	20.5879	20.0334	19.6534		19.1025	18.6101	18.1286	17.9108
	-4.6057616									0.0449	0.0275	0.0215	0.1227		0.0023	0.0023	0.0028	0.0049
VIDEO	35.6598904	K7	35.659947796971	-4.635110377207	2.9760	-1.5893	-8.0207	20.4536	21.5459	20.4112	19.8614	19.5991	19.3927		18.7513	18.3307	17.7733	17.6104
	-4.6351333		0.97484	1.29221	1.2256	2.1361	3.3777		0.0663	0.0149	0.0130	0.0262	0.0153		0.0016	0.0020	0.0030	0.0032
VIDEO	35.6610332	M2.5								21.5461	20.5580	19.9542	19.7055		19.0260	18.5364	18.0755	17.8501
	-4.5453215									0.1076	0.0137	0.0262	0.0518		0.0019	0.0021	0.0025	0.0039
VIDEO	35.6959814	K7							22.1388	20.9156	20.3969	20.1589	19.9562		19.3279	18.9173	18.3808	18.1880
	-4.5264450								0.0521	0.0287	0.0167	0.0209	0.0883		0.0026	0.0036	0.0043	0.0049
VIDEO	35.7281547	M3.5									21.0309	20.3774	20.0223		19.3492	18.8672	18.4067	18.1372
	-5.2037306										0.0243	0.0327	0.1362		0.0027	0.0029	0.0041	0.0053
VIDEO	35.8660837	M3								21.5821	20.5765	20.1285	19.8094		19.1724	18.6624	18.1648	17.9286
	-4.1075563									0.0493	0.0305	0.0296	0.0382		0.0024	0.0024	0.0042	0.0050
VIDEO	35.9623324	M2								21.1034	20.2167	19.7468	19.6287		18.8035	18.3172	17.8155	17.5798
	-4.2237615									0.0327	0.0131	0.0196	0.0342		0.0017	0.0021	0.0034	0.0045
VIDEO	35.9681759	M2.5								21.4215	20.3440	19.8795	19.6303		18.8680	18.3799	17.9367	17.7016
	-4.2573895									0.0414	0.0137	0.0135	0.1066		0.0021	0.0028	0.0028	0.0042
VIDEO	35.9729949	M1	35.972994037179	-5.204738379604		5.0723	2.6179	20.7741	21.9219	20.8275	20.0676	19.7011	19.5449		18.7733	18.2901	17.7774	17.5529
	-5.2047350		2.08523	1.37865		2.9317	3.4628		0.1150	0.0521	0.0119	0.0286	0.0575		0.0025	0.0022	0.0028	0.0039
VIDEO	36.0194131	M6									21.4811	20.5903	20.0130		19.1804	18.4466	17.9480	17.6283
	-4.8728386										0.1512	0.0271	0.1545		0.0022	0.0024	0.0021	0.0044
VIDEO	36.7075066	K2	36.707528955400	-4.530284911233		-0.4147	-9.8394	20.0023	20.4814	19.8664	19.5993	19.5159	19.4218	18.9232	18.7517	18.4144	17.9624	17.8677
	-4.5302703		0.79715	0.72506		1.7904	1.5098		0.0114	0.0133	0.0118	0.0144	0.0234	0.0017	0.0016	0.0022	0.0034	0.0040
CAL	87.7352518	K3	87.735239861645	15.881631420747		-0.8779	-2.5404	18.2273	18.9028	18.2084	17.8773	17.7695	17.6758	17.2730	17.0544	16.6104	16.2224	16.0999
	15.8816295		0.15854	0.14113		0.3188	0.2820		0.0078	0.0054	0.0026	0.0087	0.0229	0.0070	0.0035	0.0031	0.0041	0.0060
CAL	88.0439399	K5	88.043961153500	16.212597884799	0.3641	2.3316	-5.6403	18.7329	19.6508	18.7046	18.2656	18.0549	17.9226	17.4837	17.2840	16.7693	16.1954	16.0186
	16.2125856		0.59256	0.52929	0.3362	0.8564	0.7802		0.0083	0.0118	0.0087	0.0058	0.0226	0.0095	0.0044	0.0048	0.0036	0.0051
UVISTA	149.7053794	M3	149.705377978507	2.486235956106				20.7270	21.9821	21.1130	19.9467	19.3778	19.1248		18.3682	17.8524	17.3109	17.0759
	2.4862294		6.20199	11.01370					0.2167	0.0765	0.0180	0.0154	0.0320		0.0013	0.0009	0.0010	0.0010
UVISTA	149.7087571	M2.5	149.708761363556	2.78887908216031				20.6709	22.0938	20.8438	19.8575	19.4370	19.1278		18.4555	17.9656	17.4313	17.2116
	2.7888722		3.41061	5.09192					0.0243	0.0166	0.0112	0.0171	0.0227		0.0011	0.0008	0.0012	0.0018

Table 2 – *continued* Data for Final Sample

IR Survey		Spectral			Gaia				Pan-STARRS meanPSF AB mags					VISTA Vega mags				
Name	RA°	Type	RA°	Decl.°	Parallax	μ RA	μ Decl.	G	*g*	*r*	*i*	*z*	*y*	*Z*	*Y*	*J*	*H*	*Ks*
	Decl.°		± mas	± mas	± mas	± mas yr^{-1}	± mas yr^{-1}		±	±	±	±	±	±	±	±	±	±
UVISTA	149.7234241	M3.5								22.7104	21.3098	20.5154	19.9353		19.2576	18.6410	18.1390	17.8376
	2.7511805									0.1649	0.0422	0.0297	0.0848		0.0012	0.0012	0.0019	0.0021
UVISTA	149.7264829	M3.5	149.726469124665	2.590250565341				20.8861	22.7546	21.4708	20.0987	19.4587	19.0669		18.3791	17.8180	17.2913	17.0327
	2.5902461		6.90065	7.34634					0.0478	0.0270	0.0148	0.0238	0.0208		0.0013	0.0007	0.0011	0.0012
UVISTA	149.7307359	M3.5								21.8113	20.4456	19.8085	19.4070		18.7503	18.1943	17.6766	17.4237
	2.7399894									0.0307	0.0130	0.0246	0.0639		0.0010	0.0008	0.0013	0.0019
UVISTA	149.7313560	M2	149.731351713864	2.692886882358	2.2849	-5.1377	-2.4384	19.9948	21.4538	20.1508	19.3297	18.9789	18.7493		18.0241	17.5590	17.0082	16.7933
	2.6928870		0.63176	0.62314	0.8261	1.2600	1.1541		0.0214	0.0114	0.0106	0.0185	0.0312		0.0008	0.0006	0.0009	0.0009
UVISTA	149.731965	M4									21.7754	21.0125	20.3254		19.8434	19.2441	18.7651	18.4652
	2.7327131										0.0568	0.0570	0.2994		0.0022	0.0020	0.0025	0.0033
UVISTA	149.7332239	M5.5							22.8180	22.2761	20.3844	19.5777	19.2018		18.4389	17.8730	17.4382	17.1655
	2.7947267								0.1809	0.0487	0.0215	0.0164	0.0430		0.0009	0.0008	0.0013	0.0016
UVISTA	149.7355822	M2.5							22.3015	21.2084	20.2115	19.7921	19.5830		18.8246	18.3514	17.7820	17.5625
	2.3205009								0.0571	0.0209	0.0122	0.0141	0.0365		0.0010	0.0007	0.0012	0.0014
UVISTA	149.7360512	K4	149.736045993165	2.487259844103	-0.2321	-7.3325	-5.4547	19.5169	20.3606	19.4492	19.0804	18.8997	18.7779		18.0802	17.6720	17.0809	16.9594
	2.4872598		0.64011	0.37359	0.9176	0.8382	0.8325		0.0066	0.0042	0.0089	0.0113	0.0148		0.0008	0.0006	0.0009	0.0010
UVISTA	149.7476065	M2.5							22.9265	21.8455	20.7642	20.1292	19.8838		19.1804	18.6534	18.1630	17.9131
	2.7272746								0.0222	0.1171	0.0209	0.0178	0.0443		0.0016	0.0014	0.0017	0.0027
UVISTA	149.7564883	M3.5	149.756487939153	2.727999832329				20.5141	22.3374	21.0074	19.6753	19.0564	18.7287		17.9949	17.4583	16.8964	16.6443
	2.7279976		2.92877	5.22498					0.0312	0.0179	0.0104	0.0098	0.0172		0.0011	0.0008	0.0010	0.0012
UVISTA	149.7597522	M6								22.6823	20.6647	19.7397	19.3184		18.4764	17.8232	17.2872	16.9664
	2.7827541									0.0444	0.0250	0.0208	0.0301		0.0012	0.0009	0.0014	0.0015
UVISTA	149.7742789	K7	149.774279147971	2.668706544853	-0.3755	-6.9845	-12.8963	19.8543	20.9477	19.8446	19.3370	19.0638	18.9487		18.2324	17.8107	17.2140	17.0529
	2.6687115		0.63748	0.58222	0.7819	1.0446	0.9791		0.0150	0.0085	0.0144	0.0084	0.0180		0.0011	0.0008	0.0010	0.0010
UVISTA	149.7772394	M3								21.7842	20.5162	19.9210	19.4984		18.8640	18.3290	17.7934	17.5463
	2.7783479									0.0347	0.0261	0.0117	0.1116		0.0011	0.0011	0.0014	0.0018
UVISTA	149.7923194	M4	149.792307399543	2.583274196954				20.7672		21.4016	19.9016	19.2066	18.8721		18.1225	17.5830	17.1304	16.8712
	2.5832843		2.90648	4.29789						0.0565	0.0098	0.0096	0.0238		0.0012	0.0006	0.0011	0.0010
UVISTA	149.8156044	M2	149.815608819914	2.769757311106				20.5042	21.9587	20.6105	19.7011	19.2435	18.9104		18.2690	17.7772	17.2745	17.0546
	2.7697500		2.38224	4.30129					0.0351	0.0316	0.0148	0.0193	0.0332		0.0009	0.0010	0.0010	0.0013
UVISTA	149.8172140	M2	149.817198369447	2.771754406963				20.3904	22.0959	20.4851	19.6542	19.1997	18.9953		18.2823	17.8016	17.2609	17.0372
	2.7717426		2.10211	3.85719					0.0587	0.0162	0.0122	0.0203	0.0301		0.0009	0.0008	0.0013	0.0014
UVISTA	149.8251519	M3	149.825158826105	2.760822268756				20.7489	22.2857	21.0721	19.8930	19.3248	19.1166		18.3345	17.8417	17.3732	17.1457
	2.7608222		4.45694	7.53329					0.0777	0.0076	0.0134	0.0105	0.0236		0.0010	0.0007	0.0012	0.0014
CAL	276.7225557	K7	276.722547796086	4.058718034922	0.7440	1.2330	-1.1142	18.8017	19.9119	18.8163	18.3138	18.0759	17.8826	17.4972	17.2159	16.6992	16.1551	15.9994
	4.0587376		0.25266	0.27647	0.2437	0.4722	0.5167		0.0217	0.0091	0.0033	0.0028	0.0053	0.0081	0.0042	0.0036	0.0034	0.0052
CAL	276.8280740	K5	276.828044639757	3.977392480520	0.4415	-1.0556	-4.3463	18.4684	19.3584	18.4862	18.0496	17.8239	17.6885	17.2663	17.0325	16.5879	16.1728	16.0038
	3.9774041		0.15888	0.16831	0.1767	0.3142	0.3214		0.0131	0.0119	0.0033	0.0070	0.0089	0.0074	0.0035	0.0036	0.0033	0.0051
CAL	277.2399424	K7	277.239920836661	4.095191453128	0.4534	-1.9862	-5.2619	18.9085	19.9814	18.9638	18.4238	18.1466	17.9265	17.5724	17.2598	16.7456	16.3002	16.0376
	4.0952285		0.25057	0.29023	0.3339	0.4730	0.4341		0.0228	0.0087	0.0042	0.0067	0.0097	0.0085	0.0041	0.0037	0.0037	0.0052
CAL	277.2699877	K7	277.269972705599	4.522125403396	0.3592	-4.1032	-2.9879	18.9311	19.9941	18.9491	18.4395	18.1591	18.0144	17.6120	17.3401	16.7872	16.3344	16.1180
	4.5221425		0.26166	0.26634	0.3066	0.5879	0.6956		0.0158	0.0124	0.0083	0.0151	0.0058	0.0081	0.0040	0.0037	0.0037	0.0056
DXS	333.0711763	M1	333.071203143918	0.830304033314	0.1228	21.2977	-2.2154	19.6927	20.9885	19.7961	19.0524	18.6951	18.5724			17.3587	16.8191	16.5811
	0.8303505		0.61772	0.78507	0.5681	1.0132	1.1778		0.0180	0.0141	0.0108	0.0117	0.0366			0.0027	0.0029	0.0046
DXS	333.0715557	M3	333.071561677249	0.916173667634				20.9872	21.9931	21.3950	20.2114	19.6434	19.3805			18.1551	17.6539	17.3931
	0.9162355		27.75785	57.45897					0.0362	0.0237	0.0173	0.0216	0.0790			0.0035	0.0036	0.0054
DXS	333.0718253	K7	333.071813320305	1.188906051043	1.2559	-0.0237	-4.0006	20.2384	21.3538	20.2010	19.6916	19.4740	19.2395			18.2026	17.5949	17.4465
	1.1889522		1.68843	1.04016	1.9038	1.6055	1.9193		0.0572	0.0135	0.0086	0.0194	0.0583			0.0042	0.0055	0.0059
DXS	333.2839533	M3	333.283923388425	-0.410674164956				20.7836		21.3054	19.9960	19.3718	19.0911			17.7879	17.2757	17.0097
	-0.4105822		1.74142	1.61698						0.0441	0.0187	0.0091	0.0436			0.0030	0.0050	0.0048
DXS	333.2928434	M3	333.292847124344	0.734269316808	3.8847	-11.7293	-21.1246	20.3301	21.8557	20.7682	19.5504	18.9582	18.6398			17.4070	16.9648	16.6916
	0.7343005		0.79955	0.90143	0.9405	1.4193	1.5556		0.0122	0.0223	0.0140	0.0034	0.0338			0.0028	0.0033	0.0048
DXS	333.3028790	M4	333.302887172419	0.754442344733				20.6888	21.9774	21.2677	19.8465	19.1663	18.8274			17.5557	17.1132	16.8090
	0.7544734		7.12835	11.75424					0.1965	0.0374	0.0103	0.0277	0.0427			0.0035	0.0037	0.0054
DXS	333.3594622	M3								21.5006	20.3548	19.8311	19.4634			18.3002	17.8259	17.5602
	0.7512320									0.0285	0.0143	0.0738	0.0992			0.0034	0.0034	0.0057
DXS	333.3824122	M4								21.7048	20.2887	19.5484	18.9835			17.8077	17.3309	16.9979
	0.7424491									0.0436	0.0132	0.0174	0.1214			0.0028	0.0037	0.0048
DXS	333.4515020	M3	333.451575578969	0.727800712380	-0.7282	20.6346	3.6240	20.6231	21.9420	21.1563	19.8150	19.1856	18.9350			17.6807	17.2226	16.9545
	0.7278254		0.86841	1.12594	1.3384	2.9172	2.2283		0.1427	0.0470	0.0100	0.0124	0.0300			0.0044	0.0032	0.0049
DXS	333.4987510	M4							21.9939	21.6259	20.2389	19.5468	19.1100			17.9313	17.4356	17.1440
	0.7349581								0.1835	0.0487	0.0139	0.0187	0.0334			0.0034	0.0043	0.0052
DXS	333.7094552	K5	333.709446334135	0.524569397526	0.3710	-5.8741	-3.8524	19.2601	20.2572	19.1939	18.7410	18.5351	18.3885			17.2650	16.6699	16.5297
	0.5245924		0.38446	0.40323	0.4482	0.7133	0.7032		0.0115	0.0043	0.0057	0.0215	0.0366			0.0024	0.0032	0.0064
DXS	333.9366041	M1	333.936644901728	-0.947205672205	1.9967	0.3402	-7.7910	19.7115	21.1755	19.8556	19.0643	18.6820	18.5408			17.3086	16.6614	16.4942
	-0.9471891		0.64218	0.51022	0.7047	1.0896	0.9006		0.1083	0.0193	0.0091	0.0108	0.0351			0.0024	0.0058	0.0050
DXS	334.6493784	M4								21.5236	20.1513	19.5239	19.0910			17.8448	17.2731	16.9818
	1.3819891									0.0793	0.0153	0.0244	0.0358			0.0039	0.0054	0.0051
DXS	334.8182190	M4	334.818255423593	0.392802658682				20.7669	21.9217	21.2902	19.9285	19.2348	18.9691			17.6622	17.1697	16.8747
	0.3928450		2.87510	1.83692					0.1852	0.0516	0.0094	0.0230	0.0427			0.0034	0.0044	0.0054
DXS	334.9251383	K3	334.925138353308	0.727415208209		-0.8993	-5.5026	19.1814	19.8406	19.0993	18.7683	18.5935	18.4693			17.4172	16.8889	16.7754
	0.7274321		0.51157	0.39138		0.6877	0.6893		0.0174	0.0075	0.0031	0.0080	0.0182			0.0030	0.0016	0.0047
DXS	335.0303119	K2	335.030321608241	0.445380424500		5.6377	-5.3554	18.9125	19.4517	18.8504	18.6046	18.5203	18.4213			17.4399	17.0128	16.9227
	0.4454373		0.76013	0.40567		0.7263	0.6658		0.0076	0.0056	0.0032	0.0067	0.0260			0.0040	0.0035	0.0049
DXS	335.4746997	M2.5	335.474729551077	0.509174939517		12.0091	-1.3009	20.1233	21.5299	20.4693	19.3749	18.8733	18.6013			17.3604	16.7993	16.5495
	0.5091841		0.91754	0.67359		1.2168	1.4291		0.0234	0.0223	0.0070	0.0201	0.0375			0.0031	0.0034	0.0049
DXS	335.5234567	K3	335.523439344855	0.287394859518		4.9240	-7.9009	18.9031	19.5952	18.8704	18.5275	18.3543	18.2482			17.1721	16.6742	16.5423
	0.2874459		0.50264	0.27839		0.5269	0.5531		0.0122	0.0083	0.0023	0.0114	0.0113			0.0036	0.0036	0.0052
DXS	335.5823067	K7	335.582301746661	-0.144465229042		4.2254	-7.0727	19.4810	20.5273	19.4493	18.9384	18.6777	18.5472			17.3728	16.7596	16.6027
	-0.1444080		0.43214	0.50392		0.9150	0.7789		0.0318	0.0079	0.0062	0.0110	0.0226			0.0031	0.0034	0.0042
DXS	335.6150576	K2	335.615033009253	0.509092433091		-1.6997	-8.0080	18.7713	19.3124	18.7038	18.4660	18.3652	18.3305			17.2914	16.8690	16.7655
	0.5091194		0.39047	0.28177		0.5121	0.5160		0.0146	0.0096	0.0035	0.0051	0.0227			0.0027	0.0036	0.0054

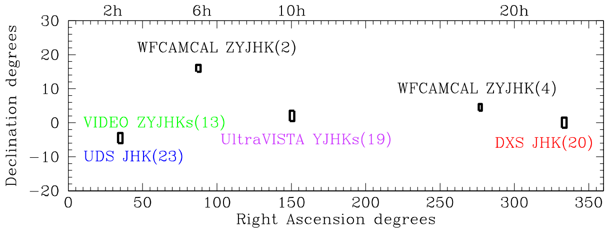

Figure 4. Sky chart showing the location and filter coverage of the final selection of standards. The number of stars at each location is given in parentheses.

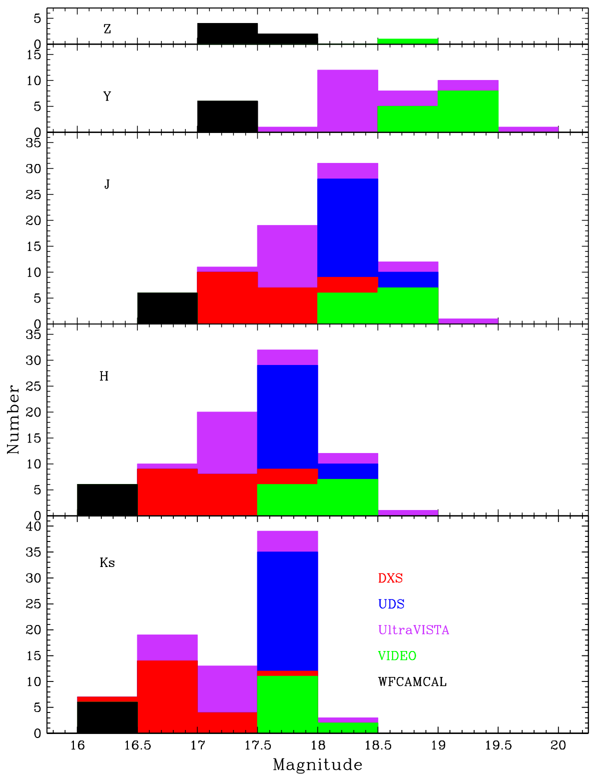

Figure 5. Histogram of magnitude distribution in each filter for each survey, for the final selection of standard stars.

9 CALIBRATION DATA

Tables 3 and 4 list the photometric calibration data for Z and Y, and Tables 5 and 6 list the photometric calibration data for $JHK(s)$, selected from the WFCAM (UKIDSS) and VISTA archives respectively. The transformations between the WFCAM and VISTA systems are given in Section 4. The uncertainties in the magnitudes which have been converted to the VISTA system includes the uncertainty in the transformation.

We only include stars with twenty or more good observations in the variability tables, for each filter, for use as calibrators. Figure 4 illustrates the location on the sky of the new photometric standards, and Figure 5 shows the magnitude distribution for each filter.

The mean magnitude from the variability table, with an uncertainty given by $1.484 \times MagMAD/\sqrt{nGoodObs - 1}$, is the fundamental photometric reference for calibration purposes. The photometry presented here has a relative uncertainty of < 0.006 mag. González-Fernández et al. (2018) and Hodgkin et al. (2009) compare the WFCAM and UKIDSS photometric systems, compare each system to the 2MASS system, and compare the WFCAM system to the FS system which is defined by a different camera on UKIRT. The authors also examine the VISTA and WFCAM colours of samples of A0 stars, which by definition are zero. These various comparisons suggest that the VISTA and WFCAM photometric accuracy is $\lesssim 0.02$ mag, which also applies to the sample of stars presented here.

10 CONCLUSIONS

The traditional near-infrared photometric standard stars published by Hawarden et al. (2001) and Leggett et al. (2006) are too bright for efficient observing by current 8- to 10-m class telescopes, and future extremely large 30- to 40-m class telescopes. In order to provide a set of fainter standards for community use, we queried the DXS, UDS, WFCAMCAL, VIDEO and UltraVISTA surveys using the WFCAM and VISTA Science Archives. Non-variable, probable stars were identified with $JHK(s)$ magnitudes between 16 and 19. The initial sample of 169 sources was further refined by excluding 77 objects that may be galaxies, as indicated by red/near-infrared colours or PAN-STARRS Kron magnitudes. Eleven of the remaining sources were excluded due to atypical colours, or discrepant aperture and mean magnitudes from the source and variability tables, respectively. In this way we have produced a sample of 81 non-variable objects with precise photometry, that are likely to be single K and M stars. The new standard stars are distributed equatorially and are accessible from both hemispheres. Table 7 collates the calibration data on the VISTA $ZYJHKs$ photometric system. The table also gives a unique running identification number for convenience — we refer to this as the Very Faint Standard, or VFS, identification number. We also give standard IAU names based on sexagesimal coordinate strings. Finder charts are presented in Appendix D.

Table 3. Standard Stars from WFCAM: *ZY*

Survey	RA° Decl.°	n Z	Z mean ± mag	Z Aper ± mag	Z rms mag	Z MAD mag	n Y	Y mean ± mag	Y Aper ± mag	Y rms mag	Y MAD mag	$Z_{\rm VISTA}$ ± mag	$Y_{\rm VISTA}$ ± mag
CAL	87.7352518	106	17.2521	17.2224	0.0732	0.0177	121	17.0335	17.0391	0.0339	0.0183	17.2730	17.0544
	15.8816295		0.0026	0.0149				0.0025	0.0138			0.0070	0.0035
CAL	88.0439399	86	17.4721	17.4935	0.1718	0.0327	103	17.2724	17.2371	0.0411	0.0218	17.4837	17.2840
	16.2125856		0.0053	0.0178				0.0032	0.0154			0.0095	0.0044
CAL	276.7225557	133	17.4837	17.4682	0.0588	0.0218	131	17.2023	17.1913	0.0544	0.0227	17.4972	17.2159
	4.0587376		0.0028	0.0173				0.0030	0.0151			0.0081	0.0042
CAL	276.8280740	140	17.2483	17.2810	0.0845	0.0203	138	17.0144	17.0237	0.0425	0.0181	17.2663	17.0325
	3.9774041		0.0026	0.0155				0.0023	0.0137			0.0074	0.0035
CAL	277.2399424	135	17.5592	17.5412	0.0638	0.0294	137	17.2465	17.2558	0.0497	0.0221	17.5724	17.2598
	4.0952285		0.0038	0.0182				0.0028	0.0160			0.0085	0.0041
CAL	277.2699877	135	17.5972	17.5926	0.0667	0.0257	133	17.3253	17.2961	0.0560	0.0218	17.6120	17.3401
	4.5221425		0.0033	0.0183				0.0028	0.0157			0.0081	0.0040

Table 4. Standard Stars from VISTA: *ZY*

Survey	RA° Decl.°	n Z	Z mean ± mag	Z Aper ± mag	Z rms mag	Z MAD mag	n Y	Y mean ± mag	Y Aper ± mag	Y rms mag	Y MAD mag
VIDEO	35.0542019						78	19.0018	18.9692	0.0327	0.0126
	-4.4813805							0.0021	0.0098		
VIDEO	35.1152774						78	19.0704	19.0412	0.0219	0.0118
	-4.9003215							0.0020	0.0088		
VIDEO	35.3795003						78	19.1025	19.0890	0.0294	0.0133
	-4.6057616							0.0023	0.0089		
VIDEO	35.6598904						77	18.7513	18.7303	0.0292	0.0094
	-4.6351333							0.0016	0.0052		
VIDEO	35.6610332						78	19.0260	18.9936	0.0234	0.0111
	-4.5453215							0.0019	0.0075		
VIDEO	35.6959814						78	19.3279	19.2979	0.0228	0.0154
	-4.5264450							0.0026	0.0105		
VIDEO	35.7281547						78	19.3492	19.3460	0.0236	0.0160
	-5.2037306							0.0027	0.0112		
VIDEO	35.8660837						78	19.1724	19.1566	0.0343	0.0143
	-4.1075563							0.0024	0.0106		
VIDEO	35.9623324						78	18.8035	18.7944	0.0206	0.0099
	-4.2237615							0.0017	0.0088		
VIDEO	35.9681759						77	18.8680	18.8437	0.0210	0.0122
	-4.2573895							0.0021	0.0288		
VIDEO	35.9729949						78	18.7733	18.8435	0.0211	0.0147
	-5.2047350							0.0025	0.0290		
VIDEO	36.0194131						78	19.1804	19.1611	0.0243	0.0128
	-4.8728386							0.0022	0.0144		
VIDEO	36.7075066	74	18.9232	18.8959	0.0460	0.0099	75	18.7517	18.7244	0.0157	0.0092
	-4.5302703		0.0017	0.0072				0.0016	0.0074		
UVISTA	149.7053794						90	18.3682	18.3562	0.0122	0.0084
	2.4862294							0.0013	0.0013		
UVISTA	149.7087571						75	18.4555	18.4382	0.0085	0.0063
	2.7888722							0.0011	0.0020		
UVISTA	149.7234241						75	19.2576	19.2364	0.0104	0.0071
	2.7511805							0.0012	0.0029		
UVISTA	149.7264829						140	18.3791	18.3591	0.0133	0.0101
	2.5902461							0.0013	0.0014		
UVISTA	149.7307359						75	18.7503	18.7310	0.0091	0.0058
	2.7399894							0.0010	0.0023		
UVISTA	149.7313560						143	18.0241	18.0070	0.0094	0.0066
	2.6928870							0.0008	0.0011		
UVISTA	149.7319650						75	19.8434	19.8107	0.0181	0.0126
	2.7327131							0.0022	0.0034		
UVISTA	149.7332239						71	18.4389	18.4214	0.0086	0.0053
	2.7947267							0.0009	0.0020		
UVISTA	149.7355822						140	18.8246	18.8101	0.0121	0.0077
	2.3205009							0.0010	0.0017		
UVISTA	149.7360512						147	18.0802	18.0609	0.0109	0.0069
	2.4872598							0.0008	0.0012		
UVISTA	149.7476065						75	19.1804	19.1586	0.0140	0.0093
	2.7272746							0.0016	0.0025		
UVISTA	149.7564883						75	17.9949	17.9755	0.0098	0.0063
	2.7279976							0.0011	0.0014		
UVISTA	149.7597522						75	18.4764	18.4621	0.0097	0.0069
	2.7827541							0.0012	0.0021		
UVISTA	149.7742789						79	18.2324	18.2136	0.0106	0.0064
	2.6687115							0.0011	0.0013		
UVISTA	149.7772394						75	18.8640	18.8447	0.0097	0.0065
	2.7783479							0.0011	0.0025		
UVISTA	149.7923194						140	18.1225	18.0959	0.0123	0.0095
	2.5832843							0.0012	0.0012		
UVISTA	149.8156044						75	18.2690	18.2479	0.0093	0.0052
	2.7697500							0.0009	0.0018		
UVISTA	149.8172140						75	18.2823	18.2632	0.0075	0.0054
	2.7717426							0.0009	0.0018		
UVISTA	149.8251519						75	18.3345	18.3074	0.0102	0.0060
	2.7608222							0.0010	0.0019		

Note: UltraVISTA Y-band source table aperture magnitudes are systematically brighter than the variability table mean magnitudes by ≈ 0.02 mag, due to differences in the aperture correction and zeropoints. All mean magnitudes given in this paper are self-consistent.

Table 5. Standard Stars from WFCAM: JHK

Survey	RA° Decl.°	n J	J mean ± mag	J Aper ± mag	J rms mag	J MAD mag	n H	H mean ± mag	H Aper ± mag	H rms mag	H MAD mag	n K	K mean ± mag	K Aper ± mag	K rms mag	K MAD mag	$J_{\rm VISTA}$ ± mag	$H_{\rm VISTA}$ ± mag	$Ks_{\rm VISTA}$ ± mag
UDS	34.0342392	349	18.3349	18.5313	0.0177	0.0108	225	17.8661	18.0749	0.0224	0.0130	513	17.5663	17.7429	0.0267	0.0141	18.3094	17.8626	17.5573
	-5.1728814		0.0009	0.0025				0.0013	0.0022				0.0009	0.0019			0.0020	0.0018	0.0032
UDS	34.0585392	350	18.5195	18.7181	0.0180	0.0108	220	18.0215	18.2202	0.0238	0.0158	522	17.7618	17.9339	0.0286	0.0173	18.4943	18.0184	17.7527
	-5.3530358		0.0009	0.0028				0.0016	0.0024				0.0011	0.0021			0.0020	0.0020	0.0032
UDS	34.0906904	351	18.3316	18.5312	0.0201	0.0117	225	17.8608	18.0636	0.0253	0.0154	516	17.5957	17.7785	0.0273	0.0147	18.3070	17.8586	17.5862
	-5.1871909		0.0009	0.0026				0.0015	0.0023				0.0010	0.0020			0.0020	0.0020	0.0031
UDS	34.1166206	350	18.3820	18.5803	0.0187	0.0119	221	17.8637	18.0607	0.0226	0.0137	522	17.6719	17.8423	0.0295	0.0191	18.3581	17.8624	17.6619
	-5.4330768		0.0009	0.0027				0.0014	0.0023				0.0012	0.0020			0.0020	0.0018	0.0032
UDS	34.1459342	352	18.4145	18.6036	0.0196	0.0125	221	17.8761	18.0775	0.0231	0.0124	524	17.6053	17.7783	0.0264	0.0173	18.3878	17.8711	17.5971
	-5.4192513		0.0010	0.0028				0.0012	0.0023				0.0011	0.0020			0.0021	0.0018	0.0033
UDS	34.1559576	352	18.5141	18.7003	0.0228	0.0129	224	17.9824	18.1923	0.0271	0.0152	516	17.7474	17.9236	0.0304	0.0199	18.4886	17.9790	17.7385
	-5.1864870		0.0010	0.0029				0.0015	0.0025				0.0013	0.0022			0.0021	0.0020	0.0033
UDS	34.1991747	353	18.3649	18.5502	0.0199	0.0138	221	17.8259	18.0177	0.0248	0.0143	524	17.5907	17.7792	0.0254	0.0170	18.3392	17.8223	17.5819
	-4.9476391		0.0011	0.0028				0.0014	0.0022				0.0011	0.0020			0.0021	0.0019	0.0033
UDS	34.2232606	386	18.5385	18.7258	0.0227	0.0139	257	17.9753	18.1769	0.0291	0.0184	604	17.7418	17.9272	0.0344	0.0215	18.5122	17.9708	17.7333
	-4.7491396		0.0010	0.0028				0.0017	0.0023				0.0013	0.0022			0.0022	0.0021	0.0034
UDS	34.2308454	351	18.3830	18.5733	0.0206	0.0130	222	17.9104	18.1110	0.0315	0.0162	535	17.6311	17.8114	0.0264	0.0186	18.3580	17.9076	17.6218
	-5.3911233		0.0010	0.0023				0.0016	0.0021				0.0012	0.0019			0.0021	0.0020	0.0032
UDS	34.3103343	348	18.5864	18.7776	0.0259	0.0143	227	18.0813	18.2905	0.0252	0.0132	533	17.7619	17.9373	0.0285	0.0169	18.5593	18.0758	17.7539
	-5.4172864		0.0011	0.0030				0.0013	0.0026				0.0011	0.0021			0.0022	0.0018	0.0034
UDS	34.3240632	345	18.5039	18.6955	0.0211	0.0149	227	17.9932	18.2027	0.0273	0.0154	530	17.6775	17.8517	0.0298	0.0174	18.4768	17.9876	17.6696
	-5.4334966		0.0012	0.0029				0.0015	0.0024				0.0011	0.0020			0.0023	0.0020	0.0034
UDS	34.3475622	345	18.3321	18.5255	0.0178	0.0110	227	17.8488	18.0557	0.0205	0.0128	531	17.5860	17.7628	0.0243	0.0150	18.3072	17.8462	17.5767
	-5.4844981		0.0009	0.0026				0.0013	0.0022				0.0010	0.0019			0.0020	0.0018	0.0032
UDS	34.3750969	345	18.5027	18.6924	0.0183	0.0109	227	17.9403	18.1475	0.0221	0.0140	531	17.6520	17.8285	0.0240	0.0149	18.4748	17.9338	17.6445
	-5.4848715		0.0009	0.0028				0.0014	0.0023				0.0010	0.0020			0.0022	0.0019	0.0034
UDS	34.4389254	339	18.3909	18.5846	0.0219	0.0131	222	17.8585	18.0665	0.0250	0.0155	517	17.6173	17.8000	0.0284	0.0192	18.3653	17.8549	17.6085
	-5.4868910		0.0011	0.0027				0.0015	0.0022				0.0013	0.0020			0.0021	0.0020	0.0033
UDS	34.5319836	439	18.4015	18.5871	0.0195	0.0119	270	17.8547	18.0507	0.0263	0.0148	627	17.6405	17.8118	0.0321	0.0213	18.3762	17.8516	17.6315
	-5.1015107		0.0008	0.0022				0.0013	0.0019				0.0013	0.0018			0.0020	0.0018	0.0033
UDS	34.6700469	374	18.3749	18.5585	0.0244	0.0165	247	17.8552	18.0493	0.0668	0.0160	576	17.5183	17.7034	0.0378	0.0265	18.3469	17.8485	17.5109
	-5.0787756		0.0013	0.0024				0.0015	0.0020				0.0016	0.0019			0.0024	0.0020	0.0036
UDS	34.6776197	404	18.4691	18.6542	0.0231	0.0140	244	17.9327	18.1342	0.0330	0.0149	594	17.6670	17.8461	0.0447	0.0257	18.4426	17.9281	17.6586
	-4.9671258		0.0010	0.0023				0.0014	0.0020				0.0016	0.0019			0.0022	0.0019	0.0035
UDS	34.7079081	347	18.1715	18.3579	0.0152	0.0095	229	17.6592	17.8669	0.0208	0.0123	533	17.5672	17.7433	0.0286	0.0166	18.1506	17.6618	17.5555
	-4.9039390		0.0008	0.0022				0.0012	0.0018				0.0011	0.0018			0.0017	0.0017	0.0029
UDS	34.7425103	345	18.2942	18.4874	0.0200	0.0129	229	17.7883	17.9945	0.0249	0.0142	529	17.7077	17.8798	0.0293	0.0193	18.2738	17.7916	17.6957
	-5.4781043		0.0010	0.0028				0.0014	0.0023				0.0012	0.0022			0.0019	0.0018	0.0029
UDS	34.7745424	371	18.4765	18.6584	0.0215	0.0125	260	17.9661	18.1642	0.0264	0.0162	595	17.6479	17.8183	0.0336	0.0210	18.4493	17.9604	17.6400
	-4.8889668		0.0010	0.0024				0.0015	0.0021				0.0013	0.0019			0.0022	0.0020	0.0034
UDS	34.8172698	354	18.6678	18.8510	0.0221	0.0148	220	18.1916	18.3840	0.0243	0.0143	521	17.9121	18.0983	0.0347	0.0194	18.6426	18.1886	17.9029
	-4.7942724		0.0012	0.0029				0.0014	0.0027				0.0013	0.0024			0.0022	0.0019	0.0033
UDS	34.8182276	404	18.5294	18.7202	0.0220	0.0122	249	17.9046	18.1129	0.0277	0.0150	619	17.7394	17.9188	0.0338	0.0221	18.5033	17.9004	17.7308
	-5.1062739		0.0009	0.0025				0.0014	0.0020				0.0013	0.0020			0.0021	0.0019	0.0034
UDS	34.8710949	366	18.3653	18.5585	0.0178	0.0112	228	17.9672	18.1734	0.0259	0.0157	536	17.8937	18.0786	0.0387	0.0240	18.3481	17.9747	17.8797
	-5.1154861		0.0009	0.0025				0.0015	0.0023				0.0015	0.0023			0.0016	0.0019	0.0029
CAL	87.7352518	136	16.6289	16.6552	0.0591	0.0219	132	16.2164	16.1917	0.0522	0.0301	136	16.1131	16.1481	0.0639	0.0424	16.6104	16.2224	16.0999
	15.8816295		0.0028	0.0160				0.0039	0.0139				0.0054	0.0229			0.0031	0.0041	0.0060
CAL	88.0439399	130	16.7948	16.7686	0.0543	0.0338	125	16.1988	16.1922	0.0559	0.0251	133	16.0276	16.0285	0.0613	0.0313	16.7693	16.1954	16.0186
	16.2125856		0.0044	0.0170				0.0033	0.0137				0.0040	0.0214			0.0048	0.0036	0.0051
CAL	276.7225557	156	16.7231	16.7228	0.0678	0.0261	157	16.1566	16.1678	0.0612	0.0271	167	16.0093	16.0034	0.0665	0.0370	16.6992	16.1551	15.9994
	4.0587376		0.0031	0.0174				0.0032	0.0151				0.0043	0.0252			0.0036	0.0034	0.0052
CAL	276.8280740	158	16.6085	16.6102	0.0485	0.0270	157	16.1697	16.1597	0.0612	0.0255	169	16.0157	16.0139	0.0750	0.0381	16.5879	16.1728	16.0038
	3.9774041		0.0032	0.0162				0.0030	0.0149				0.0044	0.0254			0.0036	0.0033	0.0051
CAL	277.2399424	156	16.7699	16.8010	0.0727	0.0270	154	16.3020	16.2767	0.0543	0.0294	168	16.0474	16.0938	0.0716	0.0369	16.7456	16.3002	16.0376
	4.0952285		0.0032	0.0187				0.0035	0.0169				0.0042	0.0263			0.0037	0.0037	0.0052
CAL	277.2699877	157	16.8103	16.8261	0.0741	0.0277	156	16.3346	16.3425	0.0621	0.0291	167	16.1284	16.1660	0.0715	0.0422	16.7872	16.3344	16.1180
	4.5221425		0.0033	0.0181				0.0035	0.0171				0.0049	0.0262			0.0037	0.0037	0.0056

Note: UDS aperture magnitudes are not aperture corrected and are systematically fainter than the mean magnitudes by ≈ 0.2 mag.

Table 5 – *continued* Standard Stars from WFCAM: ***JHK***

Survey	RA°	n *J*	*J* mean	*J* Aper	*J* rms	*J* MAD	n *H*	*H* mean	*H* Aper	*H* rms	*H* MAD	n *K*	*K* mean	*K* Aper	*K* rms	*K* MAD	J_{VISTA}	H_{VISTA}	Ks_{VISTA}
	Decl.°		± mag	± mag	mag	mag		± mag	± mag	mag	mag		± mag	± mag	mag	mag	± mag	± mag	± mag
DXS	333.0711763	26	17.3850	17.3946	0.0128	0.0067						22	16.5895	16.5916	0.0227	0.0105	17.3587	16.8191	16.5811
	0.8303505		0.0020	0.0071									0.0034	0.0068			0.0027	0.0029	0.0046
DXS	333.0715557	26	18.1809	18.1990	0.0202	0.0099						22	17.4019	17.4092	0.0224	0.0138	18.1551	17.6539	17.3931
	0.9162355		0.0029	0.0106									0.0045	0.0115			0.0035	0.0036	0.0054
DXS	333.0718253	26	18.2282	18.2278	0.0212	0.0125						22	17.4554	17.4472	0.0250	0.0155	18.2026	17.5949	17.4465
	1.1889522		0.0037	0.0109									0.0050	0.0129			0.0042	0.0055	0.0059
DXS	333.2839533	24	17.8141	17.8167	0.0133	0.0075						27	17.0182	17.0135	0.0258	0.0126	17.7879	17.2757	17.0097
	-0.4105822		0.0023	0.0089									0.0037	0.0085			0.0030	0.0050	0.0048
DXS	333.2928434	24	17.4314	17.4294	0.0159	0.0069	29	16.9668	16.9427	0.0145	0.0111	24	16.7012	16.7006	0.0245	0.0124	17.4070	16.9648	16.6916
	0.7343005		0.0021	0.0072				0.0031	0.0059				0.0038	0.0074			0.0028	0.0033	0.0048
DXS	333.3028790	24	17.5811	17.5772	0.0156	0.0095	29	17.1164	17.1209	0.0175	0.0124	24	16.8181	16.8164	0.0194	0.0145	17.5557	17.1132	16.8090
	0.7544734		0.0029	0.0077				0.0035	0.0062				0.0045	0.0077			0.0035	0.0037	0.0054
DXS	333.3594622	24	18.3253	18.3266	0.0170	0.0095	29	17.8289	17.8372	0.0277	0.0114	24	17.5693	17.5466	0.0278	0.0156	18.3002	17.8259	17.5602
	0.7512320		0.0029	0.0114				0.0032	0.0095				0.0048	0.0123			0.0034	0.0034	0.0057
DXS	333.3824122	24	17.8349	17.8492	0.0114	0.0064	29	17.3366	17.3456	0.0197	0.0122	24	17.0058	17.0084	0.0220	0.0115	17.8077	17.3309	16.9979
	0.7424491		0.0020	0.0089				0.0034	0.0071				0.0036	0.0087			0.0028	0.0037	0.0048
DXS	333.4515020	24	17.7055	17.6906	0.0147	0.0131	29	17.2250	17.2250	0.0161	0.0104	24	16.9639	16.9546	0.0193	0.0126	17.6807	17.2226	16.9545
	0.7278254		0.0040	0.0082				0.0029	0.0070				0.0039	0.0086			0.0044	0.0032	0.0049
DXS	333.4987510	24	17.9579	17.9683	0.0163	0.0092	29	17.4404	17.4481	0.0223	0.0146	24	17.1523	17.1722	0.0199	0.0134	17.9313	17.4356	17.1440
	0.7349581		0.0029	0.0094				0.0041	0.0075				0.0042	0.0096			0.0034	0.0043	0.0052
DXS	333.7094552	25	17.2900	17.2783	0.0111	0.0052	27	16.6727	16.6579	0.0205	0.0103	22	16.5390	16.5553	0.0227	0.0175	17.2650	16.6699	16.5297
	0.5245924		0.0016	0.0066				0.0030	0.0050				0.0057	0.0066			0.0024	0.0032	0.0064
DXS	333.9366041	24	17.3359	17.3307	0.0087	0.0045						24	16.5021	16.5124	0.0240	0.0126	17.3086	16.6614	16.4942
	-0.9471891		0.0014	0.0070									0.0039	0.0063			0.0024	0.0058	0.0050
DXS	334.6493784	33	17.8736	17.8719	0.0140	0.0128	20	17.2809	17.2940	0.0240	0.0154	44	16.9888	16.9910	0.0264	0.0169	17.8448	17.2731	16.9818
	1.3819891		0.0033	0.0087				0.0053	0.0077				0.0038	0.0086			0.0039	0.0054	0.0051
DXS	334.8182190	32	17.6887	17.6897	0.0187	0.0107						34	16.8830	16.8723	0.0267	0.0168	17.6622	17.1697	16.8747
	0.3928450		0.0029	0.0087									0.0043	0.0083			0.0034	0.0044	0.0054
DXS	334.9251383	31	17.4395	17.4246	0.0122	0.0093	21	16.8880	16.8930	0.0102	0.0033	34	16.7863	16.7858	0.0329	0.0148	17.4172	16.8889	16.7754
	0.7274321		0.0025	0.0074				0.0011	0.0061				0.0038	0.0078			0.0030	0.0016	0.0047
DXS	335.0303119	29	17.4586	17.4514	0.0215	0.0135	22	17.0071	17.0150	0.0140	0.0103	30	16.9359	16.9255	0.0234	0.0150	17.4399	17.0128	16.9227
	0.4454373		0.0038	0.0076				0.0033	0.0067				0.0041	0.0086			0.0040	0.0035	0.0049
DXS	335.4746997	45	17.3876	17.3823	0.0200	0.0111	33	16.8051	16.8104	0.0159	0.0119	46	16.5574	16.5396	0.0301	0.0170	17.3604	16.7993	16.5495
	0.5091841		0.0025	0.0072				0.0031	0.0054				0.0038	0.0067			0.0031	0.0034	0.0049
DXS	335.5234567	31	17.1940	17.1661	0.0169	0.0117	26	16.6729	16.6621	0.0166	0.0116	32	16.5534	16.5204	0.0242	0.0165	17.1721	16.6742	16.5423
	0.2874459		0.0032	0.0066				0.0034	0.0051				0.0044	0.0068			0.0036	0.0036	0.0052
DXS	335.5823067	28	17.3988	17.4093	0.0155	0.0086						33	16.6114	16.6016	0.0201	0.0106	17.3728	16.7596	16.6027
	-0.1444080		0.0024	0.0074									0.0028	0.0070			0.0031	0.0034	0.0042
DXS	335.6150576	31	17.3103	17.3109	0.0124	0.0083	26	16.8637	16.8537	0.0144	0.0114	32	16.7785	16.7719	0.0269	0.0180	17.2914	16.8690	16.7655
	0.5091194		0.0023	0.0070				0.0034	0.0056				0.0048	0.0078			0.0027	0.0036	0.0054

Table 6. Standard Stars from VISTA: $JHKs$

Survey	RA° Decl.°	n J	J mean ± mag	J Aper ± mag	J rms mag	J MAD mag	n H	H mean ± mag	H Aper ± mag	H rms mag	H MAD mag	n Ks	Ks mean ± mag	Ks Aper ± mag	Ks rms mag	Ks MAD mag
VIDEO	35.0542019	39	18.5465	18.5352	0.0178	0.0117	40	18.0267	18.0154	0.0331	0.0198	48	17.8310	17.8200	0.0394	0.0199
	-4.4813805		0.0028	0.0093				0.0047	0.0087				0.0043	0.0097		
VIDEO	35.1152774	39	18.5271	18.5256	0.0174	0.0085	40	18.0857	18.0768	0.0243	0.0134	48	17.8255	17.8019	0.0366	0.0225
	-4.9003215		0.0021	0.0081				0.0032	0.0080				0.0049	0.0088		
VIDEO	35.3795003	39	18.6101	18.5996	0.0138	0.0096	40	18.1286	18.1186	0.0174	0.0120	48	17.9108	17.8928	0.0369	0.0225
	-4.6057616		0.0023	0.0081				0.0028	0.0077				0.0049	0.0085		
VIDEO	35.6598904	39	18.3307	18.3223	0.0343	0.0083	40	17.7733	17.7600	0.0237	0.0126	48	17.6104	17.5946	0.0293	0.0146
	-4.635133		0.0020	0.0050				0.0030	0.0047				0.0032	0.0054		
VIDEO	35.6610332	39	18.5364	18.5202	0.0155	0.0087	40	18.0755	18.0640	0.0200	0.0104	48	17.8501	17.8392	0.0403	0.0182
	-4.5453215		0.0021	0.0070				0.0025	0.0070				0.0039	0.0076		
VIDEO	35.6959814	39	18.9173	18.9030	0.0226	0.0148	40	18.3808	18.3622	0.0287	0.0180	48	18.1880	18.1696	0.0400	0.0228
	-4.5264450		0.0036	0.0101				0.0043	0.0097				0.0049	0.0107		
VIDEO	35.7281547	39	18.8672	18.8681	0.0221	0.0121	40	18.4067	18.4025	0.0310	0.0172	48	18.1372	18.1443	0.0398	0.0244
	-5.2037306		0.0029	0.0101				0.0041	0.0098				0.0053	0.0105		
VIDEO	35.8660837	39	18.6624	18.6644	0.0170	0.0100	40	18.1648	18.1651	0.0240	0.0175	48	17.9286	17.9385	0.0383	0.0229
	-4.1075563		0.0024	0.0098				0.0042	0.0094				0.0050	0.0104		
VIDEO	35.9623324	39	18.3172	18.3222	0.0195	0.0089	40	17.8155	17.8129	0.0239	0.0142	48	17.5798	17.5857	0.0345	0.0208
	-4.2237615		0.0021	0.0080				0.0034	0.0078				0.0045	0.0086		
VIDEO	35.9681759	39	18.3799	18.3917	0.0163	0.0116	40	17.9367	17.9951	0.0207	0.0116	48	17.7016	17.7283	0.0354	0.0193
	-4.2573895		0.0028	0.0247				0.0028	0.0325				0.0042	0.0279		
VIDEO	35.9729949	39	18.2901	18.3199	0.0252	0.0092	40	17.7774	17.7690	0.0205	0.0120	48	17.5529	17.6046	0.0367	0.0182
	-5.2047350		0.0022	0.0583				0.0028	0.0551				0.0039	0.0430		
VIDEO	36.0194131	39	18.4466	18.4416	0.0169	0.0098	40	17.9480	17.9333	0.0218	0.0089	48	17.6283	17.6006	0.0367	0.0203
	-4.8728386		0.0024	0.0119				0.0021	0.0121				0.0044	0.0116		
VIDEO	36.7075066	38	18.4144	18.3932	0.0273	0.0091	40	17.9624	17.9428	0.0301	0.0142	50	17.8677	17.8408	0.0336	0.0189
	-4.5302703		0.0022	0.0073				0.0034	0.0075				0.0040	0.0082		
UVISTA	149.7053794	131	17.8524	17.8119	0.0095	0.0066	232	17.3109	17.3465	0.0362	0.0105	199	17.0759	17.0883	0.0175	0.0093
	2.4862294		0.0009	0.0012				0.0010	0.0012				0.0010	0.0012		
UVISTA	149.7087571	80	17.9656	17.9106	0.0086	0.0047	123	17.4313	17.4534	0.0155	0.0092	101	17.2116	17.2032	0.0182	0.0121
	2.7888722		0.0008	0.0019				0.0012	0.0018				0.0018	0.0019		
UVISTA	149.7234241	80	18.6410	18.5871	0.0117	0.0071	123	18.1390	18.1468	0.0238	0.0139	101	17.8376	17.8220	0.0237	0.0143
	2.7511805		0.0012	0.0027				0.0019	0.0023				0.0021	0.0024		
UVISTA	149.7264829	150	17.8180	17.7721	0.0094	0.0057	236	17.2913	17.3231	0.0750	0.0110	203	17.0327	17.0421	0.0169	0.0115
	2.5902461		0.0007	0.0012				0.0011	0.0012				0.0012	0.0012		
UVISTA	149.7307359	80	18.1943	18.1414	0.0083	0.0045	123	17.6766	17.7059	0.0194	0.0100	101	17.4237	17.4190	0.0194	0.0129
	2.7399894		0.0008	0.0021				0.0013	0.0020				0.0019	0.0020		
UVISTA	149.7313560	158	17.5590	17.5094	0.0075	0.0047	252	17.0082	17.0394	0.0394	0.0100	206	16.7933	16.8107	0.0159	0.0084
	2.6928870		0.0006	0.0011				0.0009	0.0011				0.0009	0.0011		
UVISTA	149.7319650	80	19.2441	19.1790	0.0188	0.0118	123	18.7651	18.7666	0.0308	0.0186	101	18.4652	18.4630	0.0324	0.0225
	2.7327131		0.0020	0.0031				0.0025	0.0027				0.0033	0.0031		
UVISTA	149.7332239	78	17.8730	17.8189	0.0084	0.0048	120	17.4382	17.4644	0.0167	0.0095	97	17.1655	17.1668	0.0183	0.0106
	2.7947267		0.0008	0.0018				0.0013	0.0018				0.0016	0.0019		
UVISTA	149.7355822	150	18.3514	18.3066	0.0107	0.0055	236	17.7820	17.7993	0.0887	0.0123	203	17.5625	17.5589	0.0215	0.0130
	2.3205009		0.0007	0.0015				0.0012	0.0015				0.0014	0.0015		
UVISTA	149.7360512	152	17.6720	17.6253	0.0087	0.0051	232	17.0809	17.1141	0.0622	0.0093	199	16.9594	16.9764	0.0186	0.0092
	2.4872598		0.0006	0.0011				0.0009	0.0011				0.0010	0.0012		
UVISTA	149.7476065	80	18.6534	18.6047	0.0125	0.0087	123	18.1630	18.1692	0.0262	0.0129	101	17.9131	17.9004	0.0306	0.0182
	2.7272746		0.0014	0.0023				0.0017	0.0021				0.0027	0.0022		
UVISTA	149.7564883	80	17.4583	17.4066	0.0078	0.0048	123	16.8964	16.9283	0.0164	0.0073	101	16.6443	16.6641	0.0150	0.0078
	2.7279976		0.0008	0.0013				0.0010	0.0012				0.0012	0.0013		
UVISTA	149.7597522	80	17.8232	17.7737	0.0084	0.0053	123	17.2872	17.3208	0.0191	0.0106	101	16.9664	16.9830	0.0159	0.0100
	2.7827541		0.0009	0.0018				0.0014	0.0017				0.0015	0.0018		
UVISTA	149.7742789	104	17.8107	17.7615	0.0100	0.0056	251	17.2140	17.2393	0.0799	0.0111	206	17.0529	17.0630	0.0172	0.0093
	2.6687115		0.0008	0.0013				0.0010	0.0012				0.0010	0.0013		
UVISTA	149.7772394	80	18.3290	18.2735	0.0110	0.0069	123	17.7934	17.8162	0.0248	0.0105	101	17.5463	17.5351	0.0218	0.0121
	2.7783479		0.0011	0.0023				0.0014	0.0021				0.0018	0.0021		
UVISTA	149.7923194	150	17.5830	17.5310	0.0076	0.0046	237	17.1304	17.1662	0.0826	0.0114	203	16.8712	16.8883	0.0161	0.0096
	2.5832843		0.0006	0.0011				0.0011	0.0011				0.0010	0.0011		
UVISTA	149.8156044	80	17.7772	17.7230	0.0097	0.0057	123	17.2745	17.3082	0.0174	0.0074	101	17.0546	17.0646	0.0184	0.0090
	2.7697500		0.0010	0.0018				0.0010	0.0017				0.0013	0.0018		
UVISTA	149.8172140	80	17.8016	17.7487	0.0074	0.0049	123	17.2609	17.2904	0.0202	0.0098	101	17.0372	17.0491	0.0165	0.0096
	2.7717426		0.0008	0.0018				0.0013	0.0017				0.0014	0.0018		
UVISTA	149.8251519	80	17.8417	17.7810	0.0074	0.0041	123	17.3732	17.3980	0.0165	0.0089	101	17.1457	17.1466	0.0187	0.0097
	2.7608222		0.0007	0.0018				0.0012	0.0017				0.0014	0.0018		

Note: UltraVISTA source table aperture magnitudes are systematically brighter than the variability table mean magnitudes by ≈ 0.05 mag at J, and fainter by ≈ 0.02 mag at H, due to differences in the aperture correction and zeropoints. All mean magnitudes given in this paper are self-consistent.

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Table 7. Standard Stars with VISTA-System *ZYJHKs*. The first and second columns give a unique running number for convenience (VFS = 'Very Faint Standard') and a formal IAU designation for each star.

VFS	IAU name	RA° / Decl.°	n *Z*	*Z* ± mag	n *Y*	*Y* ± mag	n *J*	*J* ± mag	n *H*	*H* ± mag	n *Ks*	*Ks* ± mag
1	UUDS J021608.22-051022.4	34.0342392					349	18.3094	225	17.8626	513	17.5573
		-5.1728814						0.0020		0.0018		0.0032
2	UUDS J021614.05-052110.9	34.0585392					350	18.4943	220	18.0184	522	17.7527
		-5.3530358						0.0020		0.0020		0.0032
3	UUDS J021621.77-051113.9	34.0906904					351	18.3070	225	17.8586	516	17.5862
		-5.1871909						0.0020		0.0020		0.0031
4	UUDS J021627.99-052559.1	34.1166206					350	18.3581	221	17.8624	522	17.6619
		-5.4330768						0.0020		0.0018		0.0032
5	UUDS J021635.02-052509.3	34.1459342					352	18.3878	221	17.8711	524	17.5971
		-5.4192513						0.0021		0.0018		0.0033
6	UUDS J021637.43-051111.4	34.1559576					352	18.4886	224	17.9790	516	17.7385
		-5.1864870						0.0021		0.0020		0.0033
7	UUDS J021647.80-045651.5	34.1991747					353	18.3392	221	17.8223	524	17.5819
		-4.9476391						0.0021		0.0019		0.0033
8	UUDS J021653.58-044456.9	34.2232606					386	18.5122	257	17.9708	604	17.7333
		-4.7491396						0.0022		0.0021		0.0034
9	UUDS J021655.40-052328.0	34.2308454					351	18.3580	222	17.9076	535	17.6218
		-5.3911233						0.0021		0.0020		0.0032
10	UUDS J021714.48-052502.2	34.3103343					348	18.5593	227	18.0758	533	17.7539
		-5.4172864						0.0022		0.0018		0.0034
11	UUDS J021717.78-052600.6	34.3240632					345	18.4768	227	17.9876	530	17.6696
		-5.4334966						0.0023		0.0020		0.0034
12	UUDS J021723.41-052904.2	34.3475622					345	18.3072	227	17.8462	531	17.5767
		-5.4844981						0.0020		0.0018		0.0032
13	UUDS J021730.02-052905.5	34.3750969					345	18.4748	227	17.9338	531	17.6445
		-5.4848715						0.0022		0.0019		0.0034
14	UUDS J021745.34-052912.8	34.4389254					339	18.3653	222	17.8549	517	17.6085
		-5.4868910						0.0021		0.0020		0.0033
15	UUDS J021807.68-050605.4	34.5319836					439	18.3762	270	17.8516	627	17.6315
		-5.1015107						0.0020		0.0018		0.0033
16	UUDS J021840.81-050443.6	34.6700469					374	18.3469	247	17.8485	576	17.5109
		-5.0787756						0.0024		0.0020		0.0036
17	UUDS J021842.63-045801.7	34.6776197					404	18.4426	244	17.9281	594	17.6586
		-4.9671258						0.0022		0.0019		0.0035
18	UUDS J021849.90-045414.2	34.7079081					347	18.1506	229	17.6618	533	17.5555
		-4.9039390						0.0017		0.0017		0.0029
19	UUDS J021858.20-052841.2	34.7425103					345	18.2738	229	17.7916	529	17.6957
		-5.4781043						0.0019		0.0018		0.0029
20	UUDS J021905.89-045320.3	34.7745424					371	18.4493	260	17.9604	595	17.6400
		-4.8889668						0.0022		0.0020		0.0034
21	UUDS J021916.14-044739.4	34.8172698					354	18.6426	220	18.1886	521	17.9029
		-4.7942724						0.0022		0.0019		0.0033
22	UUDS J021916.37-050622.6	34.8182276					404	18.5033	249	17.9004	619	17.7308
		-5.1062739						0.0021		0.0019		0.0034
23	UUDS J021929.06-050655.7	34.8710949					366	18.3481	228	17.9747	536	17.8797
		-5.1154861						0.0016		0.0019		0.0029
24	VIDEO J022013.01-042853.0	35.0542019			78	19.0018	39	18.5465	40	18.0267	48	17.8310
		-4.4813805				0.0021		0.0028		0.0047		0.0043
25	VIDEO J022027.67-045401.2	35.1152774			78	19.0704	39	18.5271	40	18.0857	48	17.8255
		-4.9003215				0.0020		0.0021		0.0032		0.0049
26	VIDEO J022131.08-043620.7	35.3795003			78	19.1025	39	18.6101	40	18.1286	48	17.9108
		-4.6057616				0.0023		0.0023		0.0028		0.0049
27	VIDEO J022238.37-043806.5	35.6598904			77	18.7513	39	18.3307	40	17.7733	48	17.6104
		-4.6351333				0.0016		0.0020		0.0030		0.0032
28	VIDEO J022238.65-043243.2	35.6610332			78	19.0260	39	18.5364	40	18.0755	48	17.8501
		-4.5453215				0.0019		0.0021		0.0025		0.0039
29	VIDEO J022247.04-043135.2	35.6959814			78	19.3279	39	18.9173	40	18.3808	48	18.1880
		-4.5264450				0.0026		0.0036		0.0043		0.0049
30	VIDEO J022254.76-051213.4	35.7281547			78	19.3492	39	18.8672	40	18.4067	48	18.1372
		-5.2037306				0.0027		0.0029		0.0041		0.0053
31	VIDEO J022327.86-040627.2	35.8660837			78	19.1724	39	18.6624	40	18.1648	48	17.9286
		-4.1075563				0.0024		0.0024		0.0042		0.0050
32	VIDEO J022350.96-041325.5	35.9623324			78	18.8035	39	18.3172	40	17.8155	48	17.5798
		-4.2237615				0.0017		0.0021		0.0034		0.0045
33	VIDEO J022352.36-041526.6	35.9681759			77	18.8680	39	18.3799	40	17.9367	48	17.7016
		-4.2573895				0.0021		0.0028		0.0028		0.0042
34	VIDEO J022353.52-051217.0	35.9729949			78	18.7733	39	18.2901	40	17.7774	48	17.5529
		-5.2047350				0.0025		0.0022		0.0028		0.0039
35	VIDEO J022404.66-045222.2	36.0194131			78	19.1804	39	18.4466	40	17.9480	48	17.6283
		-4.8728386				0.0022		0.0024		0.0021		0.0044
36	VIDEO J022649.80-043149.0	36.7075066	74	18.9232	75	18.7517	38	18.4144	40	17.9624	50	17.8677
		-4.5302703		0.0017		0.0016		0.0022		0.0034		0.0040
37	UCAL J055056.46+155253.9	87.7352518	106	17.2730	121	17.0544	136	16.6104	132	16.2224	136	16.0999
		15.8816295		0.0070		0.0035		0.0031		0.0041		0.0060
38	UCAL J055210.55+161245.3	88.0439399	86	17.4837	103	17.2840	130	16.7693	125	16.1954	133	16.0186
		16.2125856		0.0095		0.0044		0.0048		0.0036		0.0051
39	UltraVISTA J095849.29+022910.4	149.7053794			90	18.3682	131	17.8524	232	17.3109	199	17.0759
		2.4862294				0.0013		0.0009		0.0010		0.0010
40	UltraVISTA J095850.10+024719.9	149.7087571			75	18.4555	80	17.9656	123	17.4313	101	17.2116
		2.7888722				0.0011		0.0008		0.0012		0.0018

Table 7 – *continued* Standard Stars with VISTA-System *ZYJHKs*

VFS	IAU name	RA° Decl.°	n *Z*	*Z* ± mag	n *Y*	*Y* ± mag	n *J*	*J* ± mag	n *H*	*H* ± mag	n *Ks*	*Ks* ± mag
41	UltraVISTA J095853.62+024504.2	149.7234241			75	19.2576	80	18.6410	123	18.1390	101	17.8376
		2.7511805				0.0012		0.0012		0.0019		0.0021
42	UltraVISTA J095854.36+023524.9	149.7264829			140	18.3791	150	17.8180	236	17.2913	203	17.0327
		2.5902461				0.0013		0.0007		0.0011		0.0012
43	UltraVISTA J095855.38+024424.0	149.7307359			75	18.7503	80	18.1943	123	17.6766	101	17.4237
		2.7399894				0.0010		0.0008		0.0013		0.0019
44	UltraVISTA J095855.53+024134.4	149.7313560			143	18.0241	158	17.5590	252	17.0082	206	16.7933
		2.6928870				0.0008		0.0006		0.0009		0.0009
45	UltraVISTA J095855.67+024357.8	149.7319650			75	19.8434	80	19.2441	123	18.7651	101	18.4652
		2.7327131				0.0022		0.0020		0.0025		0.0033
46	UltraVISTA J095855.97+024741.0	149.7332239			71	18.4389	78	17.8730	120	17.4382	97	17.1655
		2.7947267				0.0009		0.0008		0.0013		0.0016
47	UltraVISTA J095856.54+021913.8	149.7355822			140	18.8246	150	18.3514	236	17.7820	203	17.5625
		2.3205009				0.0010		0.0007		0.0012		0.0014
48	UltraVISTA J095856.65+022914.1	149.7360512			147	18.0802	152	17.6720	232	17.0809	199	16.9594
		2.4872598				0.0008		0.0006		0.0009		0.0010
49	UltraVISTA J095859.43+024338.2	149.7476065			75	19.1804	80	18.6534	123	18.1630	101	17.9131
		2.7272746				0.0016		0.0014		0.0017		0.0027
50	UltraVISTA J095901.56+024340.8	149.7564883			75	17.9949	80	17.4583	123	16.8964	101	16.6443
		2.7279976				0.0011		0.0008		0.0010		0.0012
51	UltraVISTA J095902.34+024657.9	149.7597522			75	18.4764	80	17.8232	123	17.2872	101	16.9664
		2.7827541				0.0012		0.0009		0.0014		0.0015
52	UltraVISTA J095905.83+024007.4	149.7742789			79	18.2324	104	17.8107	251	17.2140	206	17.0529
		2.6687115				0.0011		0.0008		0.0010		0.0010
53	UltraVISTA J095906.54+024642.1	149.7772394			75	18.8640	80	18.3290	123	17.7934	101	17.5463
		2.7783479				0.0011		0.0011		0.0014		0.0018
54	UltraVISTA J095910.16+023459.8	149.7923194			140	18.1225	150	17.5830	237	17.1304	203	16.8712
		2.5832843				0.0012		0.0006		0.0011		0.0010
55	UltraVISTA J095915.75+024611.1	149.8156044			75	18.2690	80	17.7772	123	17.2745	101	17.0546
		2.7697500				0.0009		0.0010		0.0010		0.0013
56	UltraVISTA J095916.13+024618.3	149.8172140			75	18.2823	80	17.8016	123	17.2609	101	17.0372
		2.7717426				0.0009		0.0008		0.0013		0.0014
57	UltraVISTA J095918.04+024539.0	149.8251519			75	18.3345	80	17.8417	123	17.3732	101	17.1457
		2.7608222				0.0010		0.0007		0.0012		0.0014
58	UCAL J182653.41+040331.5	276.7225557	133	17.4972	131	17.2159	156	16.6992	157	16.1551	167	15.9994
		4.0587376		0.0081		0.0042		0.0036		0.0034		0.0052
59	UCAL J182718.74+035838.7	276.8280740	140	17.2663	138	17.0325	158	16.5879	157	16.1728	169	16.0038
		3.9774041		0.0074		0.0035		0.0036		0.0033		0.0051
60	UCAL J182857.59+040542.8	277.2399424	135	17.5724	137	17.2598	156	16.7456	154	16.3002	168	16.0376
		4.0952285		0.0085		0.0041		0.0037		0.0037		0.0052
61	UCAL J182904.80+043119.7	277.2699877	135	17.6120	133	17.3401	157	16.7872	156	16.3344	167	16.1180
		4.5221425		0.0081		0.0040		0.0037		0.0037		0.0056
62	UDXS J221217.08+004949.3	333.0711763					26	17.3587			22	16.5811
		0.8303505						0.0027				0.0046
63	UDXS J221217.17+005458.4	333.0715557					26	18.1551			22	17.3931
		0.9162355						0.0035				0.0054
64	UDXS J221217.24+011120.2	333.0718253					26	18.2026			22	17.4465
		1.1889522						0.0042				0.0059
65	UDXS J221308.15-002438.1	333.2839533					24	17.7879			27	17.0097
		-0.4105822						0.0030				0.0048
66	UDXS J221310.28+004403.5	333.2928434					24	17.4070	29	16.9648	24	16.6916
		0.7343005						0.0028		0.0033		0.0048
67	UDXS J221312.69+004516.1	333.3028790					24	17.5557	29	17.1132	24	16.8090
		0.7544734						0.0035		0.0037		0.0054
68	UDXS J221326.27+004504.4	333.3594622					24	18.3002	29	17.8259	24	17.5602
		0.7512320						0.0034		0.0034		0.0057
69	UDXS J221331.78+004432.8	333.3824122					24	17.8077	28	17.3309	24	16.9979
		0.7424491						0.0028		0.0037		0.0048
70	UDXS J221348.36+004340.2	333.4515020					24	17.6807	29	17.2226	24	16.9545
		0.7278254						0.0044		0.0032		0.0049
71	UDXS J221359.70+004405.8	333.4987510					24	17.9313	29	17.4356	24	17.1440
		0.7349581						0.0034		0.0043		0.0052
72	UDXS J221450.27+003128.5	333.7094552					25	17.2650	27	16.6699	22	16.5297
		0.5245924						0.0024		0.0032		0.0064
73	UDXS J221544.78-005649.9	333.9366041					24	17.3086			24	16.4942
		-0.9471891						0.0024				0.0050
74	UDXS J221835.85+012255.2	334.6493784					33	17.8448	20	17.2731	44	16.9818
		1.3819891						0.0039		0.0054		0.0051
75	UDXS J221916.37+002334.2	334.8182190					32	17.6622			34	16.8747
		0.3928450						0.0034				0.0054
76	UDXS J221942.03+004338.8	334.9251383					31	17.4172	21	16.8889	34	16.7754
		0.7274321						0.0030		0.0016		0.0047
77	UDXS J222007.27+002643.6	335.0303119					29	17.4399	22	17.0128	30	16.9227
		0.4454373						0.0040		0.0035		0.0049
78	UDXS J222153.93+003033.1	335.4746997					45	17.3604	33	16.7993	46	16.5495
		0.5091841						0.0031		0.0034		0.0049
79	UDXS J222205.63+001714.8	335.5234567					31	17.1721	26	16.6742	32	16.5423
		0.2874459						0.0036		0.0036		0.0052
80	UDXS J222219.75-000839.9	335.5823067					28	17.3728			33	16.6027
		-0.1444080						0.0031				0.0042
81	UDXS J222227.61+003032.8	335.6150576					31	17.2914	26	16.8690	32	16.7655
		0.5091194						0.0027		0.0036		0.0054

APPENDIX A: SQL QUERIES

SQL for the DXS

```
SELECT s.ra, s.dec, s.jAperMag3,v.jMeanMag,v.jnGoodObs,
s.jAperMag3err, v.jMagRms, v.jMagMAD,
s.hAperMag3,v.hMeanMag, v.hnGoodObs,
s.hAperMag3err,v.hMagRms, v.hMagMAD, s.kAperMag3,
v.kMeanMag, v.knGoodObs,s.kAperMag3err, v.kMagRms,
v.kMagMAD FROM dxsSource AS s, dxsVariabil-
ity AS v WHERE s.sourceID=v.sourceID AND
s.mergedClass=-1 AND v.variableClass=0 AND s.dec
> -30 AND v.kMeanMag>16.5 AND v.jnGoodObs>20
AND v.hnGoodObs>5 AND v.knGoodObs>20 AND
(v.jMagMAD/(SQRT(v.jnGoodObs - 1)))<=0.004
AND (v.hMagMAD/(SQRT(v.hnGoodObs - 1)))<=0.004
AND (v.kMagMAD/(SQRT(v.knGoodObs - 1)))<=0.004
AND (v.jMagRms/SQRT(v.jnGoodObs - 1))<=0.006
AND (v.hMagRms/SQRT(v.hnGoodObs - 1))<=0.006
AND (v.kMagRms/SQRT(v.knGoodObs - 1))<=0.006
AND ((s.jAperMag3 - v.jMeanMag) < 2.5 *
(SQRT(s.jAperMag3err * s.jAperMag3err
+ (v.jMagRms/SQRT(v.jnGoodObs - 1)) *
(v.jMagRms/SQRT(v.jnGoodObs - 1)))))
AND ((s.hAperMag3 - v.hMeanMag) < 2.5 *
(SQRT(s.hAperMag3err * s.hAperMag3err
+ (v.hMagRms/SQRT(v.hnGoodObs - 1)) *
(v.hMagRms/SQRT(v.hnGoodObs - 1)))))
AND ((s.kAperMag3 - v.kMeanMag) < 2.5 *
(SQRT(s.kAperMag3err * s.kAperMag3err
+ (v.kMagRms/SQRT(v.knGoodObs - 1)) *
(v.kMagRms/SQRT(v.knGoodObs - 1)))))
```

SQL for the UDS

NOTE: there is an offset between AperMag3 *and* MeanMag *due to the former not being aperture-corrected.*

```
SELECT s.ra, s.dec, s.jAperMag3,v.jMeanMag,v.jnGoodObs,
s.jAperMag3err, v.jMagRms, v.jMagMAD,
s.hAperMag3,v.hMeanMag, v.hnGoodObs,
s.hAperMag3err,v.hMagRms, v.hMagMAD, s.kAperMag3,
v.kMeanMag, v.knGoodObs,s.kAperMag3err, v.kMagRms,
v.kMagMAD FROM udsSource AS s, udsVariability AS v
WHERE s.sourceID=v.sourceID AND s.mergedClass=-
1 AND v.variableClass=0 AND v.kMeanMag>17.5
AND v.jnGoodObs>100 AND v.hnGoodObs>100 AND
v.knGoodObs>100 AND (v.jMagMAD/(SQRT(v.jnGoodObs
- 1)))<=0.004 AND (v.hMagMAD/(SQRT(v.hnGoodObs
- 1)))<=0.004 AND (v.kMagMAD/(SQRT(v.knGoodObs
- 1)))<=0.004 AND (v.jMagRms/SQRT(v.jnGoodObs
- 1))<=0.006 AND (v.hMagRms/SQRT(v.hnGoodObs
- 1))<=0.006 AND (v.kMagRms/SQRT(v.knGoodObs
- 1))<=0.006 AND s.jAperMag3err<=0.003 AND
s.hAperMag3err<=0.003 AND s.kAperMag3err<=0.003
AND (s.jAperMag3 - v.jMeanMag < 0.20) AND
(s.jAperMag3 - v.jMeanMag > 0.18) AND (s.hAperMag3
- v.hMeanMag < 0.21) AND (s.hAperMag3 - v.hMeanMag
> 0.19) AND (s.kAperMag3 - v.kMeanMag < 0.19) AND
(s.kAperMag3 - v.kMeanMag > 0.17)
```

SQL for the UltraVISTA

NOTE: there is an offset between AperMag3 *and* MeanMag *due to differences in the aperture correction and zeropoints.*

```
SELECT v.sourceID, s.ra, s.dec, v.variableClass,
s.yclassStat, s.jclassStat, s.hclassStat,
s.ksclassStat, s.yAperMag3, v.ymeanMag,
v.ynGoodObs, s.yAperMag3err, v.yMagRms,
v.yMagMAD, s.jAperMag3, v.jmeanMag, v.jnGoodObs,
s.jAperMag3err, v.jMagRms, v.jMagMAD, s.hAperMag3,
v.hmeanMag, v.hnGoodObs, s.hAperMag3err,
v.hMagRms, v.hMagMAD, s.ksAperMag3, v.ksmeanMag,
v.ksnGoodObs, s.ksAperMag3err, v.ksMagRms,
v.ksMagMAD FROM ultravistaSource AS s, ultrav-
istaVariability AS v WHERE s.sourceID=v.sourceID
AND v.variableClass=0 AND v.ksMeanMag > 16.5
AND s.hclassStat>0.7 AND s.ksclassStat>0.7
AND v.ynGoodObs>=20 AND v.jnGoodObs>=20 AND
v.hnGoodObs>=20 AND v.ksnGoodObs>=20 AND
(v.yMagMAD/(SQRT(v.ynGoodObs- 1)))<=0.004 AND
(v.jMagMAD/(SQRT(v.jnGoodObs- 1)))<=0.004 AND
(v.hMagMAD/(SQRT(v.hnGoodObs -1)))<=0.004 AND
(v.ksMagMAD/(SQRT(v.ksnGoodObs- 1)))<=0.004
AND (v.yMagRms/SQRT(v.ynGoodObs- 1))<=0.006
AND (v.jMagRms/SQRT(v.jnGoodObs- 1))<=0.006
AND (v.hMagRms/SQRT(v.hnGoodObs- 1))<=0.006
AND (v.ksMagRms/SQRT(v.ksnGoodObs- 1))<=0.006
AND ((s.yAperMag3 - v.yMeanMag) <= 0.0) AND
((s.yAperMag3 - v.yMeanMag) >= -0.04) AND
((s.jAperMag3 - v.jMeanMag) <= -0.04) AND
((s.jAperMag3 - v.jMeanMag) >= -0.08) AND
((s.hAperMag3 - v.hMeanMag) <= 0.04) AND
((s.hAperMag3 - v.hMeanMag) >= 0.00) AND
((s.ksAperMag3 - v.ksMeanMag) <= 0.02) AND
((s.ksAperMag3 - v.ksMeanMag) >= -0.02)
```

SQL for VIDEO

```
SELECT v.sourceID, s.ra, s.dec, s.mergedClass,
s.zAperMag3, v.zMeanMag,v.znGoodObs,
s.zAperMag3err, v.zMagRms, v.zMagMAD,
s.yAperMag3,v.ymeanMag,v.ynGoodObs,s.yAperMag3err,
v.yMagRms, v.yMagMAD, s.jAperMag3,v.jmeanMag,v.jnGoodObs,
s.jAperMag3err, v.jMagRms, v.jMagMAD,
s.hAperMag3,v.hmeanMag,v.hnGoodObs,
s.hAperMag3err, v.hMagRms, v.hMagMAD,
s.ksAperMag3, v.ksmeanMag,
v.ksnGoodObs,s.ksAperMag3err, v.ksMagRms,
v.ksMagMAD FROM videoSource AS s, videoVariability
AS v WHERE s.sourceID=v.sourceID AND s.mergedClass
in (-1, -2) AND v.variableClass=0 AND s.dec > -
30 AND v.ksMeanMag > 17.5 AND v.ynGoodObs>20
AND v.jnGoodObs> 20 AND v.hnGoodObs > 20 AND
v.ksnGoodObs > 20 AND (v.yMagMAD/(SQRT(v.ynGoodObs
- 1)))<=0.004 AND (v.jMagMAD/(SQRT(v.jnGoodObs
- 1)))<=0.004 AND (v.hMagMAD/(SQRT(v.hnGoodObs -
1)))<=0.004 AND (v.ksMagMAD/(SQRT(v.ksnGoodObs
- 1)))<=0.004 AND (v.yMagRms/SQRT(v.ynGoodObs
- 1))<=0.006 AND (v.jMagRms/SQRT(v.jnGoodObs
- 1))<=0.006 AND (v.hMagRms/SQRT(v.hnGoodObs
- 1))<=0.006 AND (v.ksMagRms/SQRT(v.ksnGoodObs
- 1))<=0.006 AND ((s.yAperMag3 - v.yMeanMag)
< 2.5 * (SQRT(s.yAperMag3err * s.yAperMag3err
+ (v.yMagRms/SQRT(v.ynGoodObs - 1)) *
(v.yMagRms/SQRT(v.ynGoodObs - 1)))))
```

```
AND ((s.jAperMag3 - v.jMeanMag) < 2.5 *
(SQRT(s.jAperMag3err * s.jAperMag3err
+ (v.jMagRms/SQRT(jnGoodObs - 1)) *
(v.jMagRms/SQRT(v.jnGoodObs - 1)))))
AND ((s.hAperMag3 - v.hMeanMag) < 2.5 *
(SQRT(s.hAperMag3err * s.hAperMag3err
+ (v.hMagRms/SQRT(v.hnGoodObs - 1)) *
(v.hMagRms/SQRT(v.hnGoodObs - 1))))) AND
((s.ksAperMag3 - v.ksMeanMag) < 2.5 *
(SQRT(s.ksAperMag3err * s.ksAperMag3err
+ (v.ksMagRms/SQRT(ksnGoodObs - 1)) *
(v.ksMagRms/SQRT(ksnGoodObs - 1)))))
```

SQL for WFCAMCAL

```
SELECT s.ra, s.dec, s.zAperMag3,v.zMeanMag,v.znGoodObs,
s.zAperMag3err, v.zMagRms, v.zMagMAD,
s.yAperMag3,v.yMeanMag, v.ynGoodObs,
s.yAperMag3err, v.yMagRms, v.yMagMAD, s.jAperMag3,
v.jMeanMag,v.jnGoodObs, s.jAperMag3err, v.jMagRms,
v.jMagMAD, s.hAperMag3,v.hMeanMag,v.hnGoodObs,
s.hAperMag3err,v.hMagRms, v.hMagMAD, s.kAperMag3,
v.kMeanMag, v.knGoodObs,s.kAperMag3err,
v.kMagRms, v.kMagMAD FROM calSource AS s, cal-
Variability AS v WHERE s.sourceID=v.sourceID
AND s.mergedClass=-1 AND v.variableClass=0
AND v.kMeanMag>16 AND v.ynGoodObs>100 AND
v.jnGoodObs>100 AND v.hnGoodObs>100 AND
v.knGoodObs>100 AND (v.yMagMAD/(SQRT(v.ynGoodObs
- 1)))<=0.004 AND (v.jMagMAD/(SQRT(v.jnGoodObs
- 1)))<=0.004 AND (v.hMagMAD/(SQRT(v.hnGoodObs
- 1)))<=0.004 AND (v.kMagMAD/(SQRT(v.knGoodObs
- 1)))<=0.004 AND (v.yMagRms/SQRT(v.ynGoodObs
- 1))<=0.006 AND (v.jMagRms/SQRT(v.jnGoodObs
- 1))<=0.006 AND (v.hMagRms/SQRT(v.hnGoodObs
- 1))<=0.006 AND (v.kMagRms/SQRT(v.knGoodObs
- 1))<=0.006 AND ((s.yAperMag3 - v.yMeanMag)
< 2.5 * (SQRT(s.yAperMag3err * s.yAperMag3err
+ (v.yMagRms/SQRT(v.ynGoodObs - 1)) *
(v.yMagRms/SQRT(v.ynGoodObs - 1)))))
AND ((s.jAperMag3 - v.jMeanMag) < 2.5 *
(SQRT(s.jAperMag3err * s.jAperMag3err
+ (v.jMagRms/SQRT(v.jnGoodObs - 1)) *
(v.jMagRms/SQRT(v.jnGoodObs - 1)))))
AND ((s.hAperMag3 - v.hMeanMag) < 2.5 *
(SQRT(s.hAperMag3err * s.hAperMag3err
+ (v.hMagRms/SQRT(v.hnGoodObs - 1)) *
(v.hMagRms/SQRT(v.hnGoodObs - 1)))))
AND ((s.kAperMag3 - v.kMeanMag) < 2.5 *
(SQRT(s.kAperMag3err * s.kAperMag3err
+ (v.kMagRms/SQRT(v.knGoodObs - 1)) *
(v.kMagRms/SQRT(v.knGoodObs - 1)))))
```

APPENDIX B: POSSIBLE GALAXIES

Table B1. Data for Sources Identified as Possible Galaxies

IR Survey		Flag			Gaia						Pan-STARRS meanPSF AB mags					VISTA Vega mags		
Name	RA°		RA°	Decl.°	Parallax	μ RA	μ Decl.	G	g	r	i	z	y	Z	Y	J	H	Ks
	Decl.°		± mas	± mas	± mas	± mas yr^{-1}	± mas yr^{-1}		±	±	±	±	±	±	±	±	±	±
UDS	34.0387095	1	34.038750344750	-5.393224535432	2.0828	4.0926	-8.9745	20.7447	21.9886	20.8532	20.0351	19.6112	19.3296			18.2804	17.7371	17.5162
	-5.3931529		1.43711	1.25846	1.7445	2.8440	2.8502		0.0532	0.0207	0.0182	0.0205	0.0493			0.0020	0.0018	0.0032
UDS	34.0632333	2									20.9925	20.2328	19.7778			18.5751	18.0561	17.7469
	-5.4123534										0.0323	0.0234	0.0550			0.0022	0.0022	0.0034
UDS	34.0725841	1	34.072628552341	-5.367278457759	0.8299	-0.2061	-4.3827	19.6567	19.9357	19.6258	19.5138	19.4769	19.4584			18.6107	18.3250	18.2648
	-5.3672215		0.62595	0.50292	0.8537	1.0136	0.8118		0.0124	0.0226	0.0115	0.0154	0.0358			0.0017	0.0021	0.0027
UDS	34.2131217	1	34.213113369956	-4.741901511918	0.2797	-0.3908	-3.9373	19.0469	19.3203	19.0049	18.8999	18.9062	18.9296			18.0473	17.7772	17.6997
	-4.7418757		0.37411	0.26570	0.4289	0.5696	0.4495		0.0056	0.0104	0.0060	0.0124	0.0333			0.0015	0.0018	0.0026
UDS	34.2836251	1								21.3821	20.3480	19.9655	19.5100			18.4806	17.9502	17.6859
	-5.5122054									0.0442	0.0143	0.0380	0.1018			0.0021	0.0019	0.0034
UDS	34.3328267	1								21.9449	20.7901	20.1041	19.6980			18.5164	17.9305	17.6470
	-5.2005163									0.1826	0.0256	0.0299	0.0670			0.0024	0.0021	0.0036
UDS	34.3905494	1								21.5139	20.3717	19.8806	19.4405			18.3636	17.8970	17.6138
	-5.1081487									0.0772	0.0156	0.0365	0.0262			0.0022	0.0023	0.0033
UDS	34.4226317	2	34.422696476887	-5.319394990941				20.9700	21.9304	21.1561	20.1452	19.6900	19.4092			18.3216	17.8349	17.5908
	-5.3193711		2.88829	7.68729					0.1454	0.0364	0.0123	0.0222	0.0706			0.0022	0.0019	0.0033
UDS	34.4476113	1	34.447624608681	-5.115979177256	-0.4065	-0.5852	-1.9265	19.8064	20.2081	19.7500	19.5395	19.4742	19.3670			18.4760	18.0645	17.9778
	-5.1159795		0.65716	0.53976	1.0029	0.8452	0.8947		0.0176	0.0209	0.0161	0.0194	0.0826			0.0021	0.0024	0.0032
UDS	34.4614311	1								21.7428	20.6132	20.0122	19.5653			18.4719	17.9032	17.6350
	-5.1427924									0.0493	0.0315	0.0264	0.0470			0.0023	0.0022	0.0035
UDS	34.5115289	2								21.8823	20.7066	20.0423	19.6703			18.4488	18.0040	17.6905
	-5.2450022									0.1836	0.0242	0.0221	0.0723			0.0023	0.0022	0.0033
UDS	34.5259644	1,2							21.8031	21.7587	20.5598	19.8926	19.4451			18.3814	17.9104	17.6043
	-5.2628373								0.1946	0.0513	0.0334	0.0416	0.0253			0.0022	0.0021	0.0033
UDS	34.5434314	1	34.543463866893	-5.171139515300	0.6485	-0.1422	-2.7368	19.5637	20.1365	19.4735	19.2855	19.1939	19.1399			18.1998	17.8036	17.7009
	-5.1711112		0.50344	0.35905	0.5815	0.7438	0.6398		0.0043	0.0370	0.0119	0.0140	0.0194			0.0016	0.0017	0.0028
UDS	34.5471946	1	34.547230921295	-5.176806400064	0.3174	6.3978	-9.4345	19.6890	20.1476	19.6217	19.3895	19.2849	19.1582			18.2589	17.8400	17.7102
	-5.1767668		0.55339	0.39306	0.6321	0.8295	0.7060		0.0146	0.0144	0.0098	0.0106	0.0339			0.0018	0.0017	0.0029
UDS	34.5487686	1								21.3331	20.3608	19.9194	19.4469			18.4316	17.9402	17.7101
	-5.3929635									0.0609	0.0229	0.0202	0.0669			0.0021	0.0019	0.0032
UDS	34.5590572	1	34.559105809238	-4.927423298600	-0.1536	3.8946	-3.5982	19.2729	19.5643	19.2749	19.1408	19.1434	19.1397			18.2892	18.0363	17.9828
	-4.9273779		0.60308	0.45118	0.7568	0.9018	0.7822		0.0208	0.0020	0.0108	0.0169	0.0479			0.0014	0.0020	0.0027
UDS	34.6711628	1								22.0633	20.8571	20.2795	19.8136			18.7770	18.3086	18.0321
	-5.1675618									0.1102	0.0530	0.0278	0.0633			0.0023	0.0023	0.0035
UDS	34.6858172	1	34.685894904232	-4.703061471509	0.3458	11.8361	-6.0594	19.4035	19.7527	19.3522	19.1732	19.1381	19.0562			18.1939	17.8580	17.7599
	-4.7030450		0.63685	0.48470	0.9393	0.8860	0.7466		0.0115	0.0128	0.0096	0.0110	0.0295			0.0016	0.0017	0.0027
UDS	34.7683910	2								21.8062	20.8612	20.2771	19.8818			18.7346	18.2226	17.9366
	-5.0398575									0.0160	0.0548	0.0322	0.0947			0.0022	0.0021	0.0034
UDS	34.7885620	1,2							22.1346	21.3754	20.3912	19.8497	19.4869			18.4368	17.9835	17.7201
	-4.8819019								0.1739	0.0588	0.0258	0.0361	0.0416			0.0020	0.0018	0.0033
UDS	34.8300954	1							21.9653	21.7962	20.5947	20.0403	19.6512			18.5714	18.1156	17.8530
	-5.0119407								0.1578	0.0556	0.0144	0.0215	0.0364			0.0021	0.0020	0.0032
UDS	34.8397670	2							22.6037	21.9676	20.7494	20.0257	19.6058			18.3350	17.8180	17.5136
	-4.7351863								0.2478	0.0095	0.0279	0.0278	0.0594			0.0022	0.0018	0.0034
UDS	34.8474938	1	34.847507314304	-5.335409824465				20.6009	21.8297	20.5566	19.9651	19.6698	19.3245			18.3256	17.7770	17.5709
	-5.3353341		2.19216	2.17627					0.0467	0.0499	0.0117	0.0189	0.0746			0.0021	0.0019	0.0033
UDS	34.8707629	1									21.2460	20.3159	19.6511			18.4190	17.9452	17.5810
	-5.1977157										0.0373	0.0206	0.0313			0.0022	0.0020	0.0035
UDS	34.8890054	2	34.889028664017	-4.822057442111				21.0061	22.1342	21.2954	20.2237	19.7842	19.5169			18.3800	17.8426	17.6186
	-4.8219876		3.44884	10.04841					0.1309	0.0398	0.0166	0.0195	0.0354			0.0023	0.0022	0.0035
VIDEO	35.0364084	2									21.0837	20.2244	19.7591		18.9637	18.3366	17.8180	17.5239
	-4.9878868										0.0253	0.0486	0.0730		0.0022	0.0017	0.0028	0.0039
VIDEO	35.0634277	1									20.8514	20.2694	19.7768		19.3151	18.7851	18.1603	17.9089
	-4.8899093										0.0269	0.0319	0.0136		0.0023	0.0025	0.0032	0.0040
VIDEO	35.1404271	1,2							21.9319	21.0028	20.1999	19.8095	19.3154		18.8489	18.3912	17.9152	17.7179
	-4.5489657								0.0104	0.0309	0.0243	0.0215	0.0698		0.0028	0.0024	0.0025	0.0050
VIDEO	35.1942372	1	35.194280993865	-4.866190049713		15.1823	-5.4891	20.0758	20.6159	19.9907	19.7274	19.6449	19.4795		18.9034	18.5732	18.1256	18.0160
	-4.8661564		0.68076	0.48087		1.0299	0.8569		0.0223	0.0123	0.0141	0.0150	0.0444		0.0015	0.0030	0.0035	0.0045
VIDEO	35.2729996	1							22.3620	21.9127	20.8624	20.4448	20.0550		19.4404	18.9522	18.5055	18.2381
	-5.0046632								0.2410	0.1926	0.0450	0.0543	0.0634		0.0021	0.0030	0.0054	0.0047
VIDEO	35.3783901	1								21.7415	20.8513	20.2565	19.7882		19.2379	18.7073	18.2273	17.9349
	-5.2565457									0.0291	0.0190	0.0312	0.1079		0.0022	0.0026	0.0051	0.0045
VIDEO	35.3829208	1							21.8337	20.9823	20.4489	20.1954	19.8148		19.3882	18.9576	18.3868	18.1676
	-4.9597282								0.0144	0.0513	0.0243	0.0340	0.1005		0.0023	0.0030	0.0048	0.0056
VIDEO	35.3846956	1								21.7485	20.7684	20.2319	19.8866		19.2649	18.7794	18.3458	18.0929
	-4.4494825									0.1597	0.0302	0.0201	0.0325		0.0019	0.0022	0.0044	0.0024
VIDEO	35.4517777	1	35.451819126350	-4.484091070150		1.9364	-9.6414	20.6038	21.3819	20.5229	20.1307	19.8683	19.7105		19.1223	18.7165	18.1694	18.0295
	-4.4840691		0.94865	1.11158		2.0494	2.9685		0.0351	0.0226	0.0149	0.0245	0.0322		0.0025	0.0027	0.0029	0.0044
VIDEO	35.5506321	1								21.7361	20.9951	20.5266	20.0104		19.4807	18.9698	18.4913	18.2201
	-4.6345957									0.1500	0.0219	0.0151	0.0008		0.0022	0.0024	0.0045	0.0047
VIDEO	35.5527346	1									20.9396	20.2919	19.8182		19.2588	18.7094	18.2230	17.9311
	-4.9423113										0.0302	0.0286	0.0443		0.0031	0.0024	0.0049	0.0053
VIDEO	35.6795871	1,2								21.4877	20.8680	20.5088	20.1017		19.6523	19.2109	18.7295	18.4770
	-5.2156567									0.0726	0.0352	0.0326	0.0976		0.0028	0.0038	0.0039	0.0047
VIDEO	35.7087718	1	35.708793461198	-4.837947978546	-1.8486	7.7207	-3.5925	19.6779	20.0911	19.6083	19.3864	19.2842	19.2764		18.6218	18.3506	17.9893	17.9061
	-4.8379052		0.67135	0.49583	0.6994	1.3335	1.0385		0.0190	0.0145	0.0158	0.0125	0.0424		0.0016	0.0026	0.0053	0.0055
VIDEO	35.7342835	2							21.4823	21.5245	20.2976	19.6781	19.5094		18.7360	18.2636	17.7840	17.5673
	-5.3693787								0.1503	0.0620	0.0183	0.0622	0.0402		0.0013	0.0021	0.0026	0.0038

Flag as possible galaxy: (1) $HKyJ$ and/or $HKYJ$ colour (2) one or more Pan-STARRS filters have Kron magnitudes brighter than the PSF magnitude by 0.05 mag.

Table B1 – *continued* Data for Sources Identified as Possible Galaxies

IR Survey Name	RA° Decl.°	Flag	Gaia RA° ± mas	Decl.° ± mas	Parallax ± mas	μ RA ± mas yr^{-1}	μ Decl. ± mas yr^{-1}	G	Pan-STARRS meanPSF AB mags g ±	r ±	i ±	z ±	y ±	VISTA Vega mags Z ±	Y ±	J ±	H ±	Ks ±
VIDEO	35.7408174	1								21.5238	20.6134	20.1719	19.8212		19.2800	18.8185	18.3103	18.0684
	-5.2873244									0.0496	0.0220	0.0486	0.0911		0.0020	0.0034	0.0036	0.0044
VIDEO	35.7414119	1								21.6836	20.7530	20.1849	19.7888		19.2312	18.7566	18.2657	18.0543
	-4.8313848									0.0472	0.0258	0.0118	0.0540		0.0028	0.0027	0.0054	0.0052
VIDEO	35.7655027	2							21.2297	21.2518	20.2632	19.7629	19.3965		18.7797	18.3147	17.8308	17.6399
	-5.0096975								0.0982	0.0172	0.0159	0.0173	0.0239		0.0023	0.0027	0.0022	0.0044
VIDEO	35.8265344	1							22.2128	21.0445	20.4301	20.0052	19.7425		19.2129	18.7693	18.2653	18.0430
	-4.9284675								0.0194	0.0200	0.0164	0.0264	0.0822		0.0024	0.0024	0.0046	0.0052
VIDEO	35.9375707	1									21.1609	20.5428	19.9431		19.4630	18.9046	18.4344	18.1389
	-4.4698025										0.0336	0.0366	0.1410		0.0025	0.0032	0.0047	0.0055
VIDEO	35.9460049	1								21.6890	20.8613	20.2493	19.5264		19.2133	18.6971	18.2172	17.9746
	-4.5784901									0.1515	0.0313	0.0432	0.0814		0.0024	0.0026	0.0041	0.0054
VIDEO	36.0710161	1	36.071091123688	-4.413983619399		9.7112	5.4933	20.5758	21.6183	20.5739	19.9287	19.5959	19.3285	19.0171	18.7109	18.2809	17.7485	17.5633
	-4.4139791		1.28068	0.78531		2.0081	1.8851		0.0369	0.0174	0.0093	0.0242	0.0322	0.0017	0.0015	0.0031	0.0024	0.0042
VIDEO	36.3757309	1	36.375784685588	-4.090708837809	0.7755	2.5459	-12.1766	19.6292	20.0069	19.5620	19.3690	19.3078	19.2324	18.7250	18.5751	18.2832	17.9134	17.8111
	-4.0906468		0.55848	0.44575	0.6330	1.0837	0.7780		0.0108	0.0097	0.0117	0.0124	0.0491	0.0018	0.0012	0.0021	0.0028	0.0033
VIDEO	36.6440048	1,2	36.644038728037	-4.812678556252				20.7420	21.7597	20.8992	20.1040	19.6922	19.4314	19.1277	18.8228	18.3785	17.8625	17.6593
	-4.8126421		1.46427	2.36397					0.0488	0.0123	0.0094	0.0117	0.0428	0.0020	0.0013	0.0019	0.0033	0.0035
VIDEO	36.6880308	1								21.8353	21.0651	20.4204	19.8794	19.9126	19.4749	18.9476	18.4462	18.1874
	-4.8435704									0.2784	0.0366	0.0608	0.1596	0.0031	0.0031	0.0022	0.0039	0.0041
VIDEO	36.7097084	1	36.709737717167	-4.524403538704	-1.0689	1.9018	-6.7427	20.1873	20.5807	20.0892	19.8732	19.7632	19.6094	19.2129	19.0658	18.7609	18.3770	18.2744
	-4.5243931		0.67107	0.72915	0.7793	1.5715	2.0535		0.0185	0.0116	0.0072	0.0237	0.0367	0.0016	0.0019	0.0026	0.0043	0.0049
VIDEO	52.0097291	1									20.6892	20.0223	19.5554	19.3653	18.9275	18.4124	18.0183	17.7420
	-27.6189720										0.0364	0.0276	0.0276	0.0035	0.0024	0.0028	0.0042	0.0049
VIDEO	52.4462564	1									20.6798	19.9899	19.4606	19.3498	18.8782	18.3040	17.8475	17.5704
	-27.8237538										0.0262	0.0360	0.0296	0.0034	0.0030	0.0019	0.0033	0.0049
VIDEO	52.7557893	1	52.755781300291	-27.448804052908	-0.0858	0.9688	-6.4672	20.1116	20.8253	20.0564	19.6631	19.5744	19.3967	18.9411	18.7801	18.4311	17.9267	17.8077
	-27.4488061		0.27729	0.43118	0.5462	0.6486	0.8882		0.0423	0.0191	0.0086	0.0158	0.0304	0.0040	0.0024	0.0033	0.0032	0.0056
VIDEO	52.9274555	2								21.6304	20.7160	20.3278	19.8924	19.6453	19.2771	18.8137	18.3209	18.0889
	-27.4700603									0.0417	0.0457	0.0611	0.1073	0.0030	0.0049	0.0041	0.0038	0.004
VIDEO	53.2112772	1	53.211345751370	-27.207439654263	0.7372	18.1557	-9.0152	20.8317		20.9198	20.1251	19.7043	19.5700	19.0776	18.8092	18.3537	17.9459	17.6940
	-27.2074247		0.81033	1.24769	1.6953	1.7435	2.4402			0.0388	0.0212	0.0165	0.0340	0.0022	0.0030	0.0025	0.0048	0.0046
VIDEO	53.3409644	1,2	53.340983559831	-27.845025165778	-0.7650	12.5581	-17.2877	20.8951	21.8998	20.8341	20.2670	19.9444	19.6204	19.3216	19.0852	18.6317	18.1686	17.9531
	-27.8449838		0.51344	0.97876	1.1896	1.3332	2.4270		0.1610	0.0330	0.0475	0.0201	0.0523	0.0042	0.0043	0.0018	0.0047	0.0040
CAL	87.6810876	1	87.681107197032	16.372256410953	0.5648	0.7724	-2.9455	18.3802	19.0977	18.3361	17.9998	17.8359	17.6862	17.2938	17.1385	16.6670	16.2310	16.0786
	16.3722372		0.22657	0.19663	0.2468	0.4921	0.4134		0.0037	0.0058	0.0031	0.0078	0.0102	0.0078	0.0038	0.0037	0.0043	0.0053
CAL	87.7003018	1	87.700299075751	15.824548535954	0.2557	2.3478	-1.9968	17.9648	18.5295	17.9302	17.6653	17.5282	17.4332	17.0166	16.8713	16.4748	16.1133	15.9915
	15.8245989		0.14842	0.13937	0.1558	0.3193	0.2695		0.0045	0.0029	0.0027	0.0066	0.0091	0.0070	0.0034	0.0034	0.0031	0.0043
UVISTA	149.3964243	1	149.396426037047	1.627980712026				18.0515	18.3400	18.0239	17.9150	17.8861	17.8455		17.2622	17.0280	16.7440	16.6915
	1.6279765		0.57794	0.98644					0.0118	0.0064	0.0055	0.0105	0.0158		0.0018	0.0016	0.0024	0.0041
UVISTA	149.7445300	1								22.7023	21.1733	20.5041	19.9158		19.3617	18.8135	18.2684	18.0102
	2.7571103									0.0249	0.0378	0.0375	0.0424		0.0012	0.0015	0.0018	0.0025
UVISTA	149.7772837	1								22.3306	20.9640	20.4401	19.9358		19.3635	18.8459	18.3268	18.0769
	2.7455382									0.0212	0.0270	0.0452	0.0252		0.0012	0.0008	0.0017	0.0028
UVISTA	149.7833198	1,2								22.6901	21.1603	20.3877	19.8489		19.2958	18.7427	18.2693	17.9968
	2.7839207									0.1463	0.0437	0.0358	0.0869		0.0018	0.0014	0.0020	0.0023
UVISTA	149.7947682	2	149.794759440482	2.765319258775				20.7674	21.7339	20.6624	20.1608	19.8799	19.7512		19.0779	18.6551	18.1258	17.9319
	2.7653208		3.37503	5.25135					0.0749	0.0210	0.0212	0.0273	0.0567		0.0012	0.0013	0.0018	0.0027
UVISTA	149.8276357	2								21.4163	20.0852	19.3989	19.1021		18.3504	17.8068	17.3179	17.0589
	2.7542743									0.1219	0.0230	0.0182	0.0311		0.0009	0.0007	0.0012	0.0014
CAL	312.6852216	1	312.685178912608	6.185061145961	-0.5758	-10.5551	-9.0282	18.1012	18.5962	18.0192	17.7478	17.6417	17.5611	17.1128	16.9912	16.6060	16.1981	16.0897
	6.1850892		0.17048	0.12374	0.2360	0.3446	0.2020		0.0043	0.0043	0.0047	0.0144	0.0052	0.0069	0.0037	0.0041	0.0035	0.0049
DXS	333.0678519	1	312.685178912608	6.185061145961	-0.5758	-10.5551	-9.0282	18.1012	18.7337	18.3275	18.1735	18.1308	18.0981			17.2188	16.9352	16.8494
	0.2463832		0.17048	0.12374	0.2360	0.3446	0.2020		0.0094	0.0072	0.0032	0.0050	0.0163			0.0035	0.0031	0.0050
DXS	333.1814666	1	333.071813320305	1.188906051043	1.2559	-0.023	-4.0006	20.2384	19.2513	18.8487	18.6976	18.6483	18.5967			17.7038	17.3603	17.2893
	0.5377071		1.68843	1.04016	1.9038	1.6055	1.9193		0.0059	0.0068	0.0041	0.0108	0.0176			0.0048	0.0059	0.0057
DXS	333.1895155	1	333.181502744943	0.537661770120	0.0649	3.5358	-4.0912	18.8806	19.5321	19.0986	18.9363	18.8497	18.8137			17.9090	17.5613	17.4914
	0.7402520		0.39660	0.45081	0.4259	0.6231	0.6999		0.0093	0.0038	0.0066	0.0198	0.0471			0.0035	0.0059	0.0059
DXS	333.2850037	1	333.283923388425	-0.410674164956				20.7836	22.1518	21.4454	20.0104	19.3589	18.8466			17.7170	17.1759	16.9041
	-0.9465384		1.74142	1.61698					0.1829	0.0420	0.0108	0.0166	0.0378			0.0036	0.0053	0.0055
DXS	333.4320262	2								21.7068	20.6360	19.8744	19.3903			18.0916	17.5841	17.2524
	0.7382165									0.0222	0.0136	0.0269	0.0019			0.0051	0.0052	0.0059
DXS	333.6445754	1	333.644571087727	0.534256767502	0.2749	-3.1602	-3.8142	18.4809	18.7319	18.4562	18.3525	18.3092	18.2465			17.4536	17.1791	17.1329
	0.5342898		0.25131	0.26301	0.2872	0.4120	0.4355		0.0114	0.0071	0.0029	0.0143	0.0251			0.0028	0.0038	0.0054
DXS	334.8159877	1	334.815996502933	1.097322542853	0.0244	1.5929	-10.8697	18.1228	18.4275	18.1034	17.9505	17.8859	17.8456			16.9836	16.6704	16.5741
	1.0973756		0.20974	0.22680	0.2655	0.5427	0.4169		0.0037	0.0061	0.0040	0.0050	0.0162			0.0020	0.0029	0.0047
DXS	334.9984584	1,2	334.998484432193	0.731938922959				21.0597	21.9666	21.3736	20.1511	19.4318	18.9772			17.8653	17.3730	17.0625
	0.7319926		9.42378	1 1.34213					0.1602	0.0499	0.0107	0.0106	0.0313			0.0032	0.0049	0.0055
DXS	335.0317979	2	335.031828446221	-0.109437792442	-3.5425	2.4789	7.4609	20.5124	22.1153	21.1476	19.7651	19.0880	18.7638			17.4985	17.0236	16.7454
	-0.1094196		2.07486	2.32689	2.5997	3.6136	3.9026		0.0245	0.0381	0.0109	0.0128	0.0480			0.0032	0.0038	0.0058
DXS	335.1704830	1	335.170502659949	0.510427567859	0.5604	0.1249	-8.3115	18.3110	18.7558	18.2612	18.0592	17.9900	17.9099			16.9948	16.6466	16.5527
	0.5104702		0.29755	0.28425	0.3486	0.3769	0.4869		0.0089	0.0090	0.0032	0.0066	0.0137			0.0027	0.0028	0.0054
DXS	335.3820794	2	335.382075808196	1.162262771954				20.2360	21.5394	20.2713	19.5524	19.1903	18.9633			17.7985	17.2037	16.9959
	1.1622935		2.11766	2.10523					0.0340	0.0228	0.0081	0.0130	0.0554			0.0040	0.0038	0.0046
DXS	335.6191436	1	335.619172934901	1.161866766328	0.1049	9.2640	-10.4955	18.6493	19.1149	18.6094	18.3917	18.2874	18.2377			17.2880	16.9008	16.8051
	1.1619136		0.32319	0.41983	0.3448	0.5976	0.6150		0.0163	0.0081	0.0038	0.0119	0.0160			0.0029	0.0034	0.0047

Flag as possible galaxy: (1) $HKyJ$ and/or $HKYJ$ colour (2) one or more Pan-STARRS filters have Kron magnitudes brighter than the PSF magnitude by 0.05 mag.

APPENDIX C: STARS EXCLUDED FROM THE FINAL SAMPLE

Table C1. Data for Sources Identified as Likely Stars with Atypical Colours

IR Survey		Pan-STARRS meanPSF AB mags					VISTA Vega mags				
Name	RA°	*g*	*r*	*i*	*z*	*y*	*Z*	*Y*	*J*	*H*	*Ks*
	Decl.°	± mag	± mag	± mag	± mag	± mag	± mag	± mag	± mag	± mag	± mag
UDS	34.2123189	21.7954	21.6093	20.3610	19.8250	19.4105			18.3512	17.8466	17.6092
	-4.8947515	0.1793	0.0835	0.0147	0.0315	0.1145			0.0021	0.0019	0.0033
UDS	34.4109253		21.7650	20.7175	19.9836	19.7015			18.5133	18.0228	17.7496
	-5.2700687		0.1675	0.0290	0.0255	0.0731			0.0022	0.0019	0.0033
UDS	34.5890235		21.8035	20.8665	20.1967	19.7849			18.6272	18.1619	17.9030
	-4.9424929		0.0724	0.0345	0.0278	0.0966			0.0021	0.0020	0.0033
VIDEO	35.1128282	21.6591	21.9368	20.8698	20.1845	19.8103		19.1399	18.6294	18.1766	17.9161
	-4.9552726	0.1655	0.1798	0.0538	0.0102	0.0657		0.0020	0.0025	0.0028	0.0024
VIDEO	52.0756099				20.8638	19.9288	20.2966	19.4553	18.6419	18.1248	17.7045
	-27.8683759				0.0682	0.0791	0.0063	0.0043	0.0026	0.0037	0.0050
DXS	333.3096800		21.6666	20.8225	20.1457	19.7224			18.3903	17.8713	17.5302
	0.7372219		0.1489	0.0248	0.0391	0.0516			0.0040	0.0053	0.0051
DXS	333.8609666		21.4346	20.2861	19.5578	19.1589			18.0057	17.4381	17.1374
	0.7496622		0.1123	0.0126	0.0266	0.2435			0.0055	0.0036	0.0047

Table C2. Likely Stars with Deviant Mean and Aperture Magnitudes

Survey	RA°	*Z* mean	*Z* Aper	*Y* mean	*Y* Aper	*J* mean	*J* Aper	*H* mean	*H* Aper	*K*(*s*) mean	*K*(*s*) Aper
	Decl.°	± mag	± mag	± mag	± mag	± mag	± mag	± mag	± mag	± mag	± mag
VIDEO	35.1191358			19.2971	19.2615	18.8033	18.8031	18.3092	18.3053	18.0712	18.0743
	-4.4549895			0.0025	0.0093	0.0037	0.0086	0.0035	0.0082	0.0045	0.0090
CAL	87.6786696	17.4104	17.5649	17.2602	17.2153	16.7709	16.7628	16.1723	16.1782	16.0033	16.0350
	15.8554744	0.0039	0.0183	0.0031	0.0153	0.0037	0.0172	0.0034	0.0138	0.0036	0.0211
CAL	276.8783681	17.3634	17.3458	17.0501	17.0870	16.5950	16.6020	16.0855	16.0882	16.0014	15.9022
	4.5214510	0.0031	0.0159	0.0028	0.0144	0.0030	0.0167	0.0027	0.0148	0.0040	0.0218
CAL	277.1729349	17.5923	17.6030	17.3352	17.3172	16.8237	16.8150	16.3529	16.2602	16.1989	16.0637
	4.5807735	0.0035	0.0184	0.0028	0.0159	0.0035	0.0180	0.0031	0.0161	0.0050	0.0242

APPENDIX D: FINDING CHARTS

This paper has been typeset from a TEX/LATEX file prepared by the author.

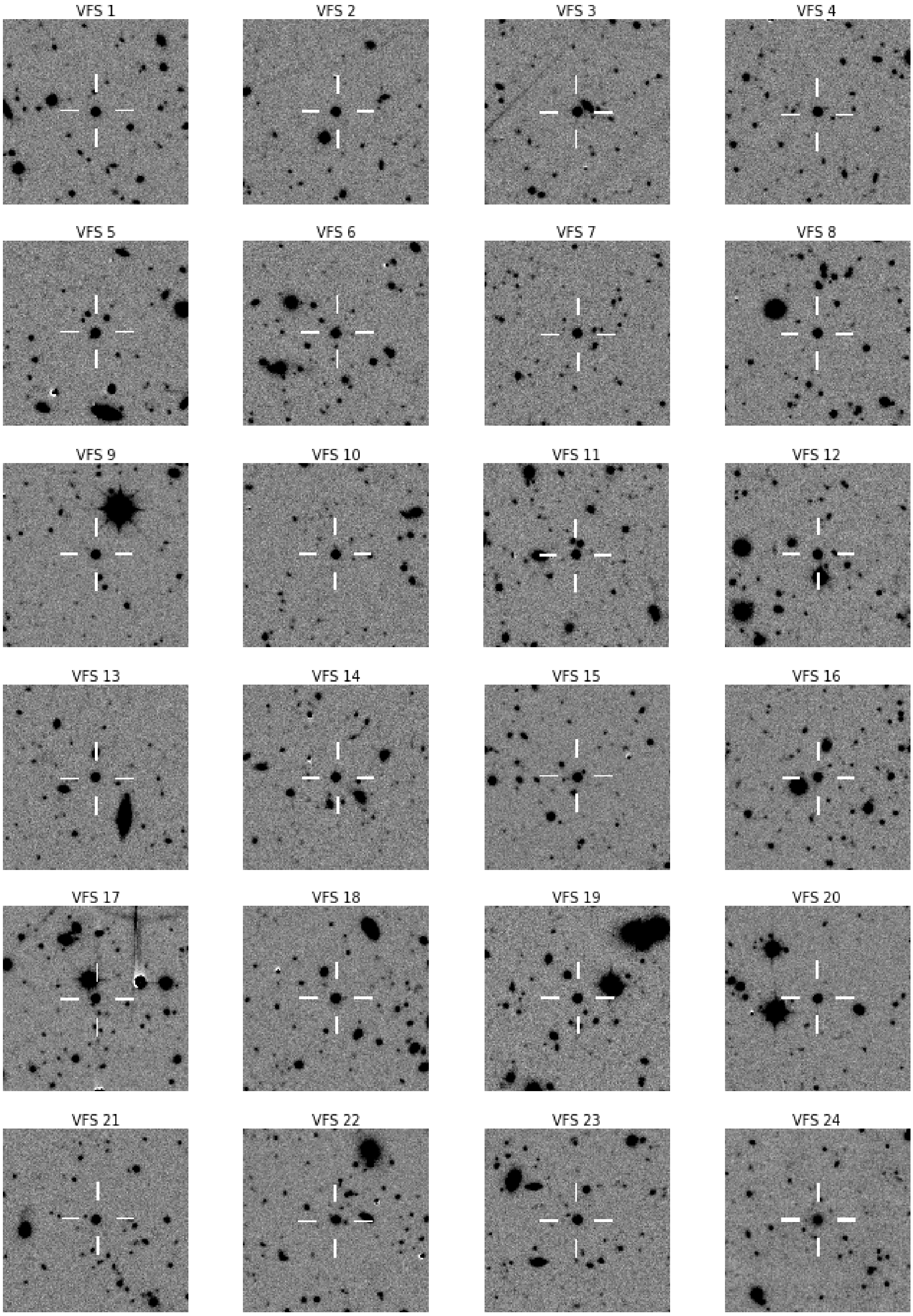

Figure D1. J–band finding charts, 1 arcminute field–of–view, for the standards presented above in Table 7. North is up and east to the left.

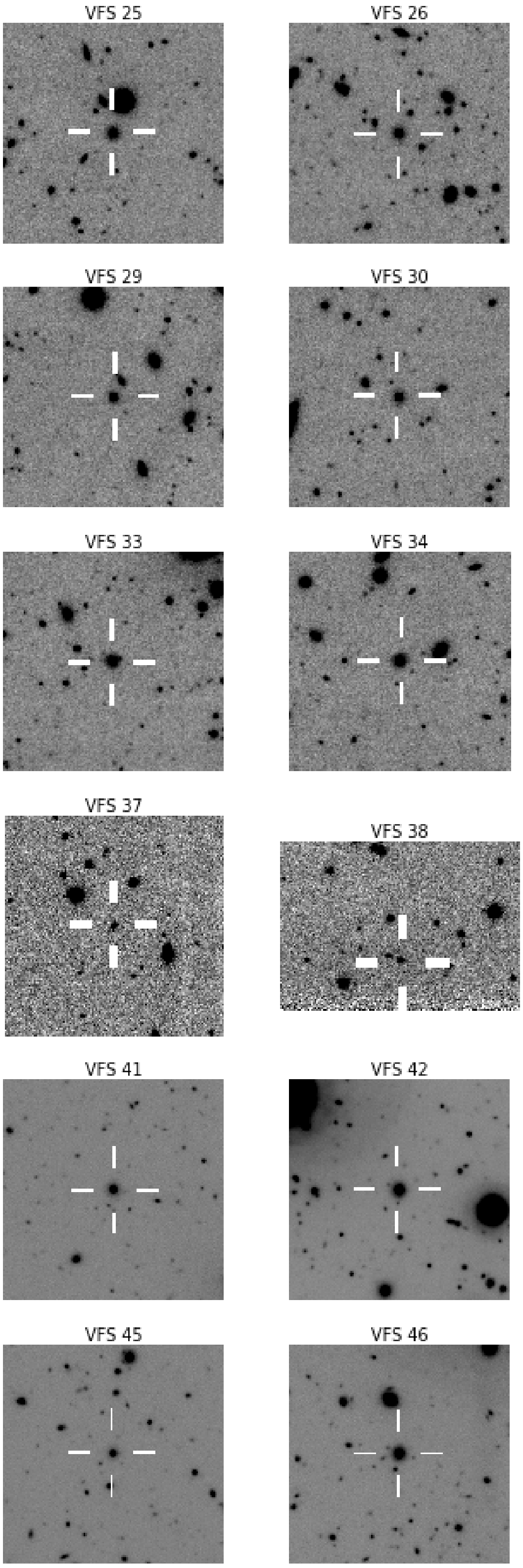

Figure D1. (cont.) J–band finding charts, 1 arcminute field–of–view, for the standards presented above in Table 7. North is up and east to the left.

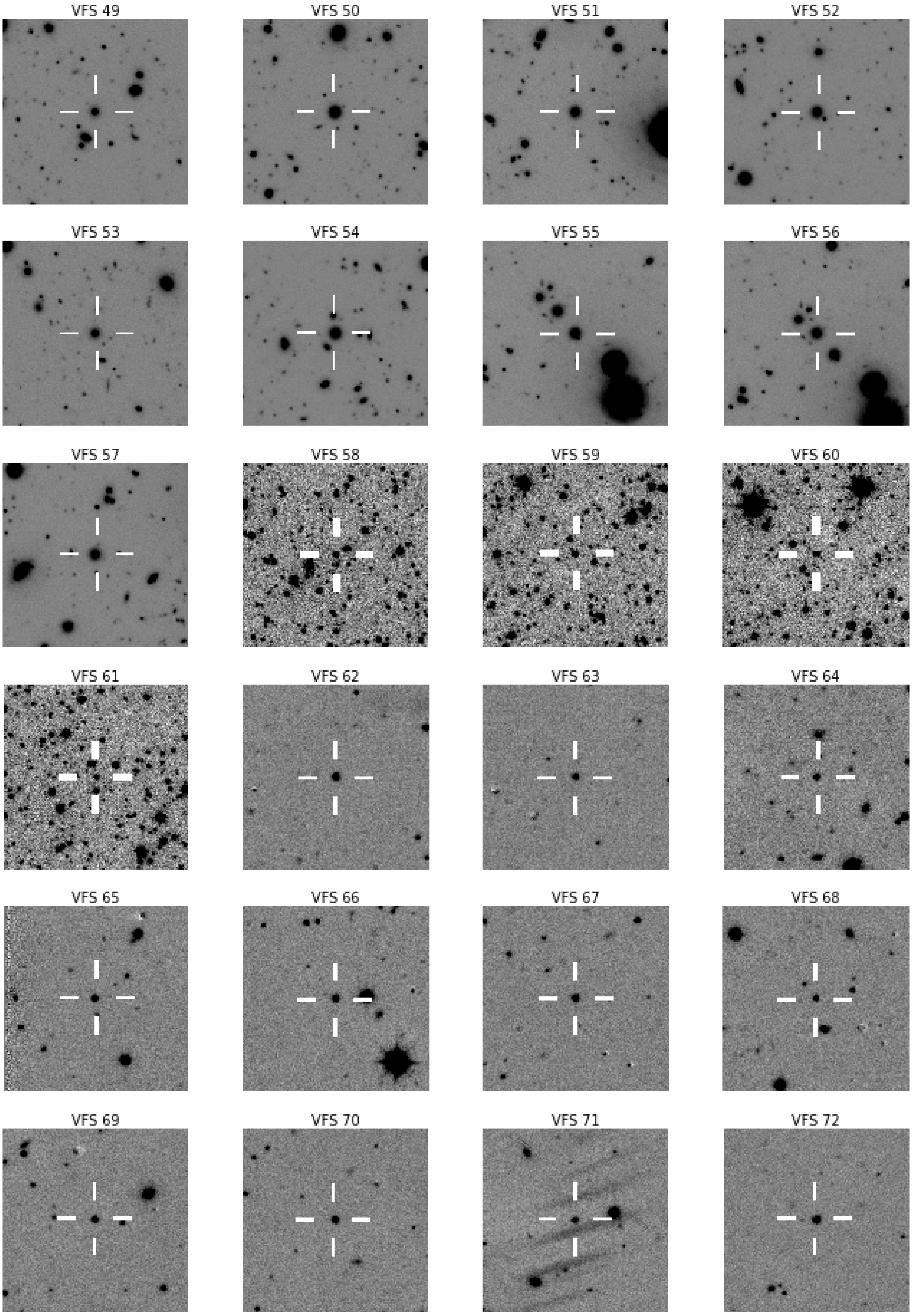

Figure D1. (cont.) J–band finding charts, 1 arcminute field–of–view, for the standards presented above in Table 7. North is up and east to the left.

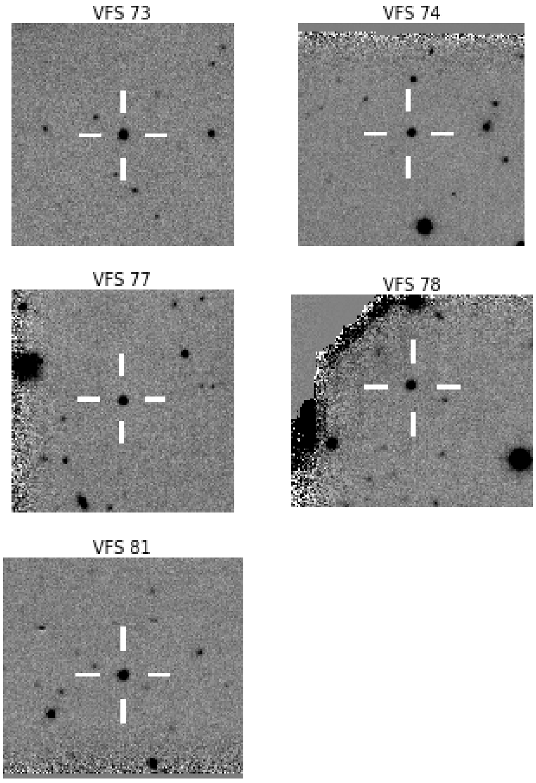

Figure D1. (cont.) J–band finding charts, 1 arcminute field–of–view, for the standards presented above in Table 7. North is up and east to the left.